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A STUDY OF PORTABLE VIBRATING TOOLS IN RELATION TO THE CLINICAL EFFECTS WHICH THEY PRODUCE

BY

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(RECEIVED FOR PUBLICATION, JANUARY 22, 1947)

During the recent war the clinical effects of the use of vibrating machinery have come even more to the fore than previously. This is because production methods, particularly in the aircraft industry, have required the increased use of portable grinding and riveting tools. Loriga (1911) first connected circulatory disturbances with the use of pneumatic tools, which had by then been in favour for many years. Pioneer work has been done by Alice Hamilton (1918), also by Rothstein and others (1918), and since then the historical facts have been described by several authors, notably Hunter and others (1945), Gurdjian and Walker (1945), and Dart (1946), so that a general survey of the literature would be of little advantage here. It is, nevertheless, worth while to consider certain tendencies in recent papers on the subject. In earlier years the reported series dealt with the effects of pneumatic tools of various kinds; in only one instance, that of "pounding up" machines (described by Middleton in 1930), which were used in the boot and shoe industry and which soon went out of use, was any other type of vibrating machine involved. The lesions brought about by pneumatic tools were: (*a*) injuries to joints; (*b*) injuries to muscles, fasciæ, and peripheral nerves; and (*c*) Raynaud's phenomenon, which occurred in the hands. Of late other ways of working have produced similar clinical manifestations, and this is not surprising in view of the widespread use in modern industry of machines which produce noise and vibrations, and the demands for ever-increasing output. Telford and others (1945) discussed Raynaud's phenomenon, which occurred in those who handled portable rotary grinding tools. Agate, Druett, and Tombleson (1946) likewise reported it occurring in those who ground small iron castings against large belt-driven grinding wheels. In this instance there was no vibrating tool, but the castings were firmly held in the fingers and vibrated whilst being ground.

Dart (1946) and Peters (1946) have found a rather different clinical picture in those who use a light high-speed rotary grinding-tool driven by an air turbine. In their series of cases, the symptoms consisted of pain, numbness, stiffness, and swelling, and these predominated over the physical signs, which appeared to be variable and indefinite. They did not observe the periodical blanching of the fingers in response to cold, which is the main feature of vascular disturbances hitherto reported. Gurdjian and Walker (1945) add to the earlier reports on pneumatic tools a series of six cases of Raynaud's phenomenon occurring in those who had used a light portable riveting hammer in one hand while they steadied the work with the other; the industry was aircraft construction, the affected hand was that which held the work and not the one which held the tool, and all the sufferers were women.

The published work on vascular disturbances of occupational origin clearly demonstrates that vibration is a factor common to all outbreaks. The hardness of the materials worked upon has been mentioned—Seyring (1930), while Alice Hamilton (1918) and Bridge and Middleton (1925) thought that the excessive strength of the men's grip ought to be considered. At first the physical characteristics of the vibrations attracted little notice, but Leake (1918) had estimated the primary vibrations from limestone cutting tools at 3,000 to 3,500 per minute, with subsidiary vibrations up to 10,000 per minute. Gerbis and others (1931) found that tools in the shoe trade were responsible for vibrations of 17,000 to 36,000 per minute, or 280 to 600 per second, and they produced Raynaud's

phenomenon very rapidly. Hunt (1936) stated that the riveting hammer causing his cases worked at 2,300 strokes per minute and weighed 13 lb. McLaren (1937) suggested that the same frequency was critical, but some of his men had acquired the disease from tools of different speeds ; these speeds were not stated. Cummins (1940) quoted the same figure, and alleged that tool speeds beyond 2,300 strokes per minute were hazardous. Mills (1942) thought tools at 3,000 strokes per minute were more likely to produce lesions than those at slower rates. The evidence for some of these statements does not appear to be complete.

The women in the series of Gurdjian and others (1945) worked with 3-lb. pneumatic hammers of 3,000 to 3,400 strokes per minute, which is a higher critical frequency than some previous authors allow. Hunter and others (1945) studied groups of men using tools of different speeds on different jobs, and, from the relative incidence of disease in each group, suggested that tool speeds of 2,000 to 3,000 strokes per minute would be best avoided. Their suggestion, and our own experience of cases resulting from the tools described by Telford and others (1945), in which a rotation speed of 2,900 revolutions per minute is mentioned, has prompted us to make a closer study of the vibrations themselves.

Besides the frequency, it is necessary to study the amplitude and form of the vibrations, and to recognize that few except of the simplest kind are in the form of pure " notes," depictable graphically as sine wave curves. Most have complex wave forms which can conveniently be expressed in terms of a fundamental frequency of large amplitude, upon which are imposed various harmonics of progressively higher frequency and smaller amplitude. Peters (1946) mentions that engineers had estimated at 0·001 to 0·002 in. the amplitude of the vibrations arising from the use of special high-speed tools working at about 2,500 revolutions per minute ; but their method of determining this is not stated. Dart (1946), describing the same series, briefly writes of an attempt to use a cathode-ray oscillograph to study frequencies and amplitudes. The method later had to be abandoned, but a rate of 12,000 vibrations per minute, and an amplitude of 0·003 in. is mentioned in his paper.

A tool may be said to have a speed of so many strokes or revolutions per minute (r.p.m.). This figure will determine the fundamental frequency of the vibration, but it is not justifiable to assume that this is the damaging one. It is already recognized that the biological effects of high-frequency sounds, or high-frequency alternating currents, are different from those of lower ones. We have outlined a method (Agate and Druett, 1946) for rapidly recording vibrations in terms of the frequency and amplitude of all the individual harmonics. Briefly, the method depends upon placing a crystal pick-up on the vibrating surface and putting the electrical response which it generates through a series of filters, so that the fraction in each frequency band appears quantitatively upon a fluorescent cathode-ray screen and can be photographed and measured. The analysing instrument is an adaptation of an acoustic spectrometer. The frequency and size of the harmonics can, within certain limits, be calculated in terms of cycles per second, and millimetres (or microns) respectively. We found that the technique can be used for any sort of vibrating machine, whether piston-operated or rotary, and even when the type of vibration changed from moment to moment. This was so in the study of the grinding of small castings, where the first results by the present authors' method were reported. The crystal pick-up in a special mounting can lie under the hand, and it responds to vibrations at right angles to its flat surface, so it can record the actual vibration likely to impinge on the surface of the hand in various circumstances.

The Present Investigation

The scope of the work was to apply this analytical method to the vibrations coming from a small but fairly representative collection of tools working under normal conditions. First, there might exist a relationship between the type of vibration coming from a tool and the type or incidence of the lesion it produced in patients. Secondly, the effect of different mechanical factors in the design of tools might be judged. Thirdly, the relative merits of different methods of doing the same piece of engineering work could be weighed up ; and, fourthly, a trial could be made of the efficacy of various absorbent materials which had already been suggested for preventing the vibrations from reaching the hands.

The tools examined fell naturally into two classes, regardless of the motive power they used. First, there were those which depended for their effectiveness upon the to-and-fro motion of a piston. The majority of compressed-air tools are of this kind, for example rock drills, road rippers, mechanical picks, riveting and chipping hammers, and scaling hammers. There are a few similar tools, driven electrically, in which the oscillation is set up by an eccentrically placed weight, but we did not have an opportunity to examine this type ; it is unlikely to differ much from the air-driven machines. In all these types a succession of hammer blows is the

method of work, and vibration is inevitable. Moreover, the vibration is not so much a continuous oscillation, as a series of short pulses with relatively long pauses between them. Rock drills can be included in this group, though their action is double ; the piston oscillates to and fro, but also rotates a certain distance with each stroke. The tool steel thus has an intermittent rotary motion supplemented by hammer blows. Its effective action is one of continuous, slow boring into hard rock, and the whole rock drill might not be expected to vibrate to and fro to the same extent as a road ripper or pneumatic pick, despite the fact that there is within it a heavy oscillating piston.

The second group of tools comprises those which rotate and are held in the hands, such as polishing and grinding equipment, whether these are driven by air turbine, by portable electric motor incorporated in the tool, or by a flexible cable passing from a fixed motor to the handpiece. Vibration is not essential to the effective working of these tools ; the better they are made, the less there is, although when they are used for grinding vibration is inevitable.

PISTON-OPERATED TOOLS

Introduction

The suggestion of Hunter and others (1945) that the critical damaging frequency for these tools lies between 2,000 and 3,000 strokes per minute is probably true, but the problem can be looked at from other points of view. Tools of this kind are constructed to work at from 1,000 to 8,000 beats per minute (b.p.m.), but the rate varies inversely with the size and weight of the tool and with the heaviness of the job to be done. A light-weight riveting hammer of from 3,000 to 8,000 b.p.m. is used for small cold rivets and can be held in the hands with ease. A heavy road ripper weighing 75 lb. may work at only 1,000 to 1,200 b.p.m. Certain of the hand-operated rock drills weigh from 30 to 56 lb. and work at 1,750 to 2,300 b.p.m., and all these larger tools are usually used pointing downwards ; the weight of the tool does the work, and the man must lean his own weight on the handles in addition ; but while it is held vertically he need not maintain the same continuously powerful grip that he would use in supporting the tool in the horizontal position. The strength of the man's grip was called in question some time ago (Alice Hamilton, 1918). It is significant that relatively few cases of Raynaud's phenomenon have been reported from men working with these slower, heavier road rippers and drills working downwards ; we did not hear of any in the course of our inquiries. But the position is very different in the case of riveting hammers and pneumatic chisels of various sorts. These have to be held horizontally, the physical work is done by the weight of the man's body lunging forward, and the tool is held up only by the strength of his grip. The weight of such tools is of the order of 12 to 20 lb. The vibration resulting from this kind of work is intense and almost painful, as anyone may discover who tries it. It is found also that tools of this size most often work at 1,700 to 3,500 b.p.m. (though a few are rated at 1,050 and others at 6,000 b.p.m.).

Before the tool speeds of 2,000 to 3,000 per minute are incriminated, it is well also to remember that these frequencies are the ones usually selected for work which is particularly arduous, which requires a specially firm continuous grip, and which is associated with the most intense vibration. Riveting is typical of such work. Hunter and others stated that 53·5 per cent. of riveters working at 2,000 b.p.m. had " white fingers," compared with 74 per cent. of a group working at 2,000 to 3,000 b.p.m. Their tables showed, of the latter group, that 20 out of 27 (74 per cent.) had done the work for between 11 and 20 years or more, whereas in the former group 22 out of 43 (51 per cent.) had worked there less than 10 years. Had the duration of the work been the same in both series, the incidence of the disease might have been more equal, for it has several times been pointed out that the longer a man works in this way the greater his chance of developing Raynaud's phenomenon (Seyring, 1930 ; Agate, Druett, and Tombleson, 1946).

We were allowed, through the courtesy of a firm of pneumatic tool manufacturers, to experiment upon their models then in production. The tools were handled by experienced men, and records were taken with the tools working for the most part upon the materials for which they were designed. Rock drills and road rippers were worked on granite blocks, pneumatic chisels and chipping hammers were made to cut steel plate, and riveting hammers were tested while forming hot steel rivets in thick armour plate. As already stated, the larger the pneumatic tool, the slower is its rate of working. Many of those studied were working at rates well below 2,000 b.p.m., though the rates were not exactly those given in the specifications, owing to changes in the pressure of the air supply and the amount of muscular force being applied. We found that a modification of the original analytical method was necessary, because our acoustic spectrometer was not designed to record at frequencies lower than 40 cycles per second (2,400 per minute). Readings were therefore taken as usual on the spectrometer to find the higher harmonics, but the fundamental was calculated by passing the pick-up response into a double-beam cathode-ray oscillograph, comparing the " trace " on the screen with that simultaneously produced by 50-cycle alternating current, and photographing the screen. The films were enlarged, and pictures (fig. 1).

TABLE 1

THE VIBRATION FROM PISTON-OPERATED PNEUMATIC TOOLS

Tools	Road ripper	Chipping hammer			Coal pick	Rock drill	Large riveting hammer	Small riveting hammer		Scaling hammer
		Large	Medium	Small			Hot rivets	Hot rivets	Cold rivets	
Weight ..	75 lb.	13¾ lb.	12¾ lb.	7¼ lb.	29½ lb.	30 lb.	20½ lb.	13¾ lb.		4½ lb.
Nominal tool speed	1,050 b.p.m.	1,700 b.p.m.	3,500 b.p.m.	6,000 b.p.m.	1,350 b.p.m.	2,300 b.p.m.	1,050 b.p.m.	1,700 b.p.m.		4,500 b.p.m.
Recorded fundamental (cycles per sec.)	15·5	approx. 28	approx. 40	approx. 64	?	approx. 40		approx. 25 to 32		approx. 64

Amplitude

Hand	Left	Left	Right	Left	Right	Left	Right	Left	Right	Right	Left	Right	Left	Right	Left	Right	Left	Right
Fundamental	57·15 mm.	?	?	4·3 mm.	16·5 mm.	4·25 mm.	17·4 mm.	?	?	0·88 mm.	?	?	?	?	?	?	0·46 mm.	0·10 mm.
1st harmonic (frequency)	3·55 mm. (31 ∽)	1·55 mm. (50 ∽)	14·2 mm. (50 ∽)	0·69 mm. (80 ∽)	4·1 mm. (80 ∽)	0·6 mm. (125 ∽)	2·9 mm. (125 ∽)	0·27 mm. (40 ∽)	3·0 mm. (40 ∽)	0·11 mm. (80 ∽)	?	?	0·45 mm. (50 ∽)	0·72 mm. (64 ∽)	0·31 mm. (50 ∽)	1·3 mm. (64 ∽)	0·11 mm. (125 ∽)	?
Spectrometer frequency band (cycles per second) 40	mm. 1·06	mm. 1·9	mm. 12·5	mm. 4·3	mm. 16·5	mm. 1·9	mm. 13·0	μ 270	mm. 3·0	μ 880	μ 810	mm. 3·7	300	μ —	300	μ 320	μ 180	μ —
50	μ 290	1·55	14·2	1·05	3·6	1·88	9·3	170	1·2	280	270	1·18	450	280	310	mm. 1·17	320	—
64	335	1·82	4·8	μ 880	5·6	4·25	17·4	130	μ 720	215	135	1·42	390	720	300	1·3	460	105
80	99	μ 455	2·75	690	4·15	μ 760	4·0	58	175	110	88	μ 790	159	160	93	μ 400	126	—
100	47	400	1·78	300	1·2	375	1·72	37	130	84	76	460	93	72	81	200	60	—
125	30	253	1·09	195	μ 700	595	2·95	27	105	49	51	220	72	86	78	67	114	—
160	17	155	μ 360	116	550	186	μ 840	21	50	37	41	170	50	40	46	23	25	—
200	10	74	300	64	255	166	550	13	13	33	22	55	27	—	26	—	23	—
250	5	40	160	39	180	79	290	11	—	29	15	23	14	7·3	21	—	19	—
320	3·1	28	125	31	65	51	190	10	—	18	11	—	10	5·5	11	—	18	2·6
400	1·4	18	66	18	33	33	100	6·0	3·2	8·0	5·2	—	5·6	—	5·8	7·6	3·7	—
500	0·95	11	31	11	15	22	53	2·5	3·0	4·6	2·9	—	2·9	—	3·6	12·0	1·6	—
640	0·62	9·2	19	7·7	8·9	14	32	1·7	3·2	3·6	1·3	—	1·7	1·7	2·8	9·4	1·6	0·5
800	0·82	7·1	11	6·4	4·2	10	19	1·4	3·3	3·0	1·0	5·2	1·1	1·1	2·6	5·9	1·3	0·5
1,000	0·5	6·4	8·8	4·6	3·1	8·3	14	1·2	2·6	3·8	0·8	4·6	1·0	1·2	2·0	3·5	0·5	0·5
1,250	0·12	6·4	10·3	4·3	2·5	6·9	11	1·0	2·6	3·9	0·9	5·0	0·8	1·4	0·8	2·1	0·8	0·4
1,600	0·03	3·4	8·3	2·7	1·5	5·1	7·6	0·5	2·9	3·0	0·5	3·4	0·6	1·2	0·8	1·3	0·4	0·2
2,000	trace	2·5	3·7	1·9	2·0	4·3	6·5	0·2	2·2	1·6	0·3	1·4	0·4	0·9	0·5	1·0	0·2	0·2
2,500	,,	2·9	2·9	2·6	1·4	4·3	5·9	0·1	2·6	0·9	0·2	1·0	0·3	0·6	0·3	1·1	0·1	0·1
3,200	—	2·8	3·2	2·6	0·6	4·1	8·2	trace	1·5	0·4	trace	0·7	0·2	0·4	0·2	0·7	trace	trace
4,000	trace	0·7	1·8	0·8	0·4	1·6	4·3	,,	0·8	0·1	,,	0·4	0·1	0·4	0·1	0·5	—	,,
5,000	,,	0·2	2·0	0·2	0·5	0·5	1·2	,,	0·3	trace	,,	0·2	trace	0·3	trace	0·5	—	,,
6,400	,,	0·1	1·1	0·1	0·4	0·3	0·8	,,	0·2	,,	,,	0·2	,,	trace	,,	0·5	—	,,
8,000	,,	trace	0·1	0·1	0·1	0·2	0·4	,,	0·1	,,	,,	0·1	,,	,,	,,	0·2	—	,,
10,000	,,	,,	0·1	trace	0·1	0·1	0·3	,,	trace	,,	,,	trace	,,	,,	,,	trace	—	,,
12,000	—	,,	0·1	,,	trace	trace	0·2	,,	,,	,,	,,	,,	,,	,,	,,	,,	—	,,
16,000	trace	,,	trace	,,	,,	,,	0·1	,,	,,	,,	,,	,,	,,	,,	,,	,,	—	,,
Column No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

TABLE 2

THE VIBRATION FROM PISTON-OPERATED PNEUMATIC TOOLS COMPILED FROM THE DATA OF TABLE 1

Tool	Road ripper	Chipping hammer						Coal pick		Rock drill	Large riveting hammer		Small riveting hammer				Scaling hammer	
Hand	Left	Large		Medium		Small		Left	Right	Right	Left	Right	Hot rivets		Cold rivets		Left	Right
		Left	Right	Left	Right	Left	Right						Left	Right	Left	Right		
Amplitude of fundamental (frequency)	57·15 mm. (15·5 ∿)	?	?	4·3 mm. (40 ∿)	16·5 mm. (40 ∿)	4·25 mm. (64 ∿)	17·4 mm. (64 ∿)	?	?	0·88 mm. (40 ∿)	?	?	?	?	?	?	0·46 mm. (64 ∿)	0·1 mm. (64 ∿)
Amplitude of 1st harmonic (frequency)	3·55 mm. (31 ∿)	1·55 mm. (50 ∿)	14·2 mm. (50 ∿)	0·69 mm. (80 ∿)	4·15 mm. (80 ∿)	0·6 mm. (125 ∿)	2·95 mm. (125 ∿)	0·27 mm. (40) ∿	3·0 mm. (40 ∿)	0·11 mm. (80 ∿)	?	?	0·45 mm. (50 ∿)	0·72 mm. (64 ∿)	0·31 mm. (50 ∿)	1·3 mm. (64 ∿)	0·11 mm. (125 ∿)	?
Highest frequency (in cycles per second) at which the respective standard amplitudes are present																		
Standard amplitude mm. 1·0	40	72	125	50	100	80	160	—	50	—	—	72	—	—	—	64	—	—
Standard amplitude μ 100	80	180	360	160	320	250	400	64	125	80	80	180	100	100	80	125	80	64
Standard amplitude μ 10	200	640	800	500	640	800	1,250	320	200	400	320	250	320	250	320	640	360	—
Standard amplitude μ 1·0	500	4,000	6,400	4,000	2,500	5,000	5,700	1,250	4,000	2,500	800	2,500	1,000	2,000	1,250	2,500	800	640
Standard amplitude μ 0·1	1,250	6,400	12,500	8,000	10,000	10,000	16,000	2,500	8,000	4,000	2,830	8,000	4,000	6,400	4,000	10,000	2,500	2,500
Column No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

were produced which enabled the frequency to be read off; then, after computation of the Fourier series by 24 ordinates, the amplitude of the fundamental and the first few harmonics could be calculated.

The Grip Used on the Piston-operated Pneumatic Tools

To interpret the results it is necessary to know how each tool is handled, so for ease of description let it be assumed that all the workers are right-handed and hold the tools in the most usual way. Road rippers and rock drills (figs. 2 and 3) are most often used with the operator leaning his weight upon the double handle, with his arms straight, both wrists fully dorsi-flexed, and the fingers gripping on the handles, which are usually covered with firm rubber. The tool "steel" drills a hole in which the machine can stand upright by itself, so that for most of the time the grip need not be as strong as would be needed for weight lifting. The shock is borne directly across the palms and at right angles to their surface. Pneumatic coal picks (fig. 4) are usually provided with a single handle at the base, which is held in the right hand. Such a tool is used in all positions, and the worker steadies the thick barrel at its mid-point on the front of his left hand and fingers, but the main shock is borne by the right hand which is transmitting the weight of his body. Riveting and chipping hammers (figs. 5 and 6) are held much as a pick is held, but they are usually worked horizontally, and the hands have to steady the tool and support its weight. The right hand holds the pistol grip and is subjected to the whole force of a to-and-fro vibration which travels along the long axis of the tool. The left hand grips near the working end, or on the tool steel itself, and it is subjected to vibration in all directions, though the main to-and-fro vibration does not impinge at right angles to the palm and fingers, but instead exerts a rolling action from side to side. The vibration pick-up was in all cases placed at the point where most pressure would be applied; that is, when under the right hand it recorded the principal displacement to and fro, and when under the palm of the left hand it recorded the general vibration and "chatter" in directions at right angles to the first. When a scaling hammer (fig. 7) is used, the cutting steel works in and out at right angles to the long axis of the tool; the left hand presses it against the surface to be scaled, and therefore absorbs the main vibration, whereas the right hand in this case merely steadies the end and the compressed air hose.

The Results Recorded from Piston-Operated Pneumatic Tools

The results recorded from piston-operated pneumatic tools are shown in Table 1. This table records the amplitudes in millimetres or microns at the various frequencies which make up the complete spectrum as far as 16,000 cycles per second. But from these columns of 27 values, which diminish at different rates and which show maximum values at different points, it is not always easy to decide on the severity of the total vibration, nor is it even easy to say whether one tool is better or worse than another. Table 2 has therefore been constructed to make interpretation easier. It is based upon the supposition that a vibration, for example, of 30 microns at 1,000 cycles is more severe than one of 30 microns at 100 cycles, for the energy involved in a vibration (that is, the potential damaging force) depends on the product of the amplitude squared and the frequency squared. Table 2 records the highest frequency at which an amplitude of 1 millimetre, 0·1 millimetres, 10 microns, 1·0 microns, and 0·1 microns respectively was present. These will be referred to henceforward as "standard amplitudes." Approximations had to be made throughout, and where figures fell well between two frequencies, the mean of the two was taken. A set of high figures in Table 2 indicates that relatively large amplitudes were present at high frequencies, and therefore that the vibration is intense. Consideration of each column, and at the same time of the size of the larger (i.e. fundamental) amplitudes, appears to give a reasonable picture of the conditions set up by each tool. By this means the tools may be placed in order of the hazard they might reasonably produce, but strict quantitative comparison between them must be made only with great caution.

The Road Ripper.—This tool (fig. 2) was the standard model and is commonly used all over the country for road-breaking operations. It was driven downwards into a block of granite, but its steel was specially blunted so that conditions could be kept constant longer than would have been the case if the block had been broken up with a sharp steel. The weight was 75 lb., and the designed speed was 1,050 b.p.m., so that the fundamental frequency should have been 17·5 cycles per second. In fact, it was 15·5 cycles per second, and at this frequency the enormous amplitude of 57·15 mm. was present. At 40 cycles 1·0 mm. was present; 100 μ appeared as high as at 80 cycles, 10 μ at 200 cycles, 1 μ at 500 cycles, and 0·1 μ at about 1,250 cycles per second.

A new experimental road ripper was also tested. It appeared to be a considerable improvement on the older model, having lower values at the fundamental and other low frequencies, but 1·0 μ and 0·1 μ amplitude appeared, for all that, higher in the spectrum than with the previous type.

The Chipping Hammers (*Pneumatic Chisels*).—Three machines of this type were tried, weighing 13¾ lb., 12¾ lb., and 7¼ lb., and designed to work at 1,200, 3,500, and 6,000 b.p.m. respectively. For comparison they were all made to work on the same operation, that of cutting ⅜ in. steel plate, which they did with ease. The small tool (fig. 6) did the work more slowly and set up a very intense vibration, since it was probably being overloaded. It should be noted from the tables that the two smaller ones had fundamental amplitudes of 16·5 and 17·4 mm. at 40 cycles and 64 cycles respectively. These are formidable figures, and at these frequencies are much

higher than other tools produce, even if the latter sometimes produce greater amplitudes at lower frequencies. In the case of one of these chisels there was 0·1 μ present at the extreme upper end of the recordable spectrum (16,000 cycles). In each case the intensity of vibration impinging on the left hand was apparently much less than that on the right. This has already been foreshadowed. When in use these tools need the strongest possible grip to keep them steadily on the job; an inexperienced worker cannot handle them at all.

The Coal Pick.—This type of tool (fig. 4) is extensively used in mines to break coal from the seams. In our experiments it was used horizontally against a granite block, a material which is somewhat harder than that for which it was intended. Its weight was 29½ lb., and its rate of working 1,350 b.p.m., which should give a fundamental at about 22 cycles per second. The amplitude of the fundamental could not in this case be determined because of the complexity of the wave form, but consideration of the first harmonic suggests that it is comparable with that of the road rippers. The left hand in this case was subjected to much less vibration than from any machine so far considered, while the right hand seemed to be subjected on this tool to about as much as the left hand received from the chipping hammers.

The Rock Drill.—The rock drill chosen was one which would normally be hand-operated (fig. 3). There are many other types of rock drill, but most of them are supported on steel beams or made to work, as in "stoping," with one end pressed against the surface of the rock, so in neither case would the drill have to be held very firmly in the hands. The chosen tool was used working vertically downwards in its native granite. Since it had two similar handles at the base, the effect on each hand was equal, and readings were taken from under the right hand only, at right angles to the long axis of the machine. The crystal was strapped to a standard rubber handgrip on the handle. The weight of the drill was 30 lb., the speed 2,300 b.p.m., and the action rotary and boring in type, as already described. The vibrations were relatively small, the fundamental (at approximately 40 cycles per second) was only 0·88 mm. Nowhere was 1·0 mm. recorded, and above 4,000 cycles all appreciable vibration was absent. It was not possible to try this tool without rubber handgrips, so the effect of these is indeterminate.

The Riveting Hammers.—Two riveting hammers were tested under normal conditions. One weighed 13¾ lb. and worked at 1,700 b.p.m.; the other (fig. 5) weighed 20½ lb. and worked at 1,050 b.p.m. Unfortunately, no opportunity presented itself for trying out any faster and smaller riveting tools.

All such tools require a very powerful grip for efficient working. Our experiments were done while driving rivets into prepared holes in a steel plate against an automatic pneumatic "holder-up." The rivets were ¾ in. in diameter for the smaller hammer, and 1⅛ in. for the larger. Experimentally, some were driven while hot and some while cold, but in practice such large rivets would always be driven hot. The nominal fundamental frequencies were 28 cycles and 17·5 cycles, but the records proved too complex for the corresponding amplitudes to be accurately computed. They were obviously high.

It will be seen that the vibration in riveting is not quite so intense as that from chipping hammers, but it is nevertheless large. Riveters, moreover, tend not to be casual labourers but to work with these tools for many years. Cold riveting seems to produce somewhat more vibration than hot riveting, whether judged by the size of the fundamental or by the range; but this is true for the right hand only. In the left hand the figures for hot and cold riveting are equal, to within the limits of experimental error. The contention that there is some significance in the hardness of the material worked upon is only poorly borne out here. In any case, different work on different materials usually requires a different size of tool, and different conditions would apply. As previously, the left hand apparently absorbs less vibration than the right during either hot or cold riveting.

The Scaling Hammer.—This tool (fig. 7) weighed only 4½ lb. and had a small piston-operated cutting head working at right angles to the long axis of the tool. It worked at 4,500 b.p.m. The left hand would be expected to undergo most disturbance, and this appears so from the figures. The grip needs to be less powerful with this tool than that required for a riveting or chipping hammer. There is less disturbance from a scaling hammer than there is from any other piston-operated tool in the series.

ROTATING TOOLS

Introduction

The tool which Telford and others (1945) described is relatively new compared with the pneumatic hammers. It consisted of a handgrip through the centre of which a spindle rotated on ball-bearings. On to this spindle many different kinds of "heads" for cutting, grinding, or polishing metal could be fixed. The driving power came through a flexible covered cable from an electric motor fixed on the bench or suspended from the roof. In such tools the motor may be from ½ to 1½ horsepower, and there are pulleys which allow of three different spindle speeds. These machines were found to be very useful for cleaning and "burring" aluminium alloy castings and polishing all manner of steel parts for aero engines, and they were used in increasing numbers as the war progressed. Our experience of various makes of these tools led us to think that these differ in detail, but not in principle or application. In the last-mentioned paper the authors stated that the higher rates of revolution, the hardness of the material worked upon, and the bluntness of the cutters were the significant factors responsible for increasing the damaging vibrations. They suggested that the risk of vascular disturbances is probably insignificant if the speed is below 2,000 revolutions per minute (r.p.m.). Theirs, however,

was a clinical study, and experimental data in support of their contention were lacking. Whitwell (1945), in a published letter, drew attention to many other factors in these tools which require consideration. He pointed out that there are a number of different " heads " of widely different diameters ; there are different speeds ; the spindles are of variable length ; and the longer the spindle, the greater the " whip " which results. The shaft ought to be kept lubricated and the balance adjusted, and the flexible cable should not be allowed to kink. He suggested that unskilled men tend to press harder than they need, and allow the tool to jump about in their hands. It was clearly profitable to investigate some of these suggestions experimentally. Also, since the work of Dart (1946) and Peters (1946), who reported from America a new clinical picture from the use of different vibrating rotary tools working at 25,000 r.p.m., there has arisen an even greater need for recording the vibrations produced.

We set out to take records from as many types of rotary drilling, grinding, and polishing tools as were readily available. A few, which we studied at the works where the pneumatic hammers were made, were driven by air turbines. The remainder were collected together in the shops and the experimental vibration laboratories of an aircraft factory. At this factory it was customary to use these tools for " scurfing " duralumin engine castings with rotary cutters. For polishing steel castings, such as centre bosses or " barrels " of large air-screws, they had three methods available. Method A (fig. 8) was to use the tool just described with stones and polishing buffs mounted on the spindle. The casting rested on the bench. Method B was to use a portable grinding wheel, driven by an electric motor incorporated in the body of the tool (fig. 9). In method C the casting was grasped in the hands, allowed to rest on the thigh, and applied to a large grinding wheel which was either belt-driven or fixed to the spindle of a powerful motor fixed on a bench mounting (fig. 10).

The conditions of method A were studied as follows. The acoustic spectrometer and crystal pick-up were used as before. The services of an experienced foreman from the polishing shop were provided. He was a right-handed man and always held the tool with his left hand in a pronated position in front near the " head," and with his right hand further back on the handpiece (fig. 11). The flexible drive cable passed along his right forearm. Cutting heads were tried out on a bulky block of cast duralumin, and grinding and polishing " bobs " or buffs on a large hollow steel casting. The machines could be run at any of three speeds, and readings were taken either with the tool idling or when working with a normal side-to-side stroke. While the tool was idling, the records remained steady enough for one reading only to be necessary ; while it was working, the records were less steady, and the mean of three was always taken. The pick-up in its special mounting was strapped to the cylindrical handpiece directly under each hand in turn, at the level of the heads of the metacarpals. A few records were also taken from the back of the hand, the elbow, and the shoulder, and will be described later.

The following studies were made :

(*a*) of the vibration reaching the left and right hands ;

(*b*) of that set up by various types of " heads " working at their optimum speeds on the usual material, that is, the cutters at medium speed (approximately 2,900 r.p.m.) on duralumin, and the stones or buffs at high speeds (while idling, approximately 8,300 r.p.m.) on the steel ;

(*c*) of the effect of different degrees of out-of-truth of the $\frac{1}{4}$ in. diameter projecting spindle on which the heads were mounted ;

(*d*) of the effect on the vibrations of handpieces and cables which had worn to varying degrees ;

(*e*) of the effect of wrapping round the handpieces various absorbent materials—namely, a $\frac{1}{2}$-in. thickness of sorbo sponge rubber, cloth-covered corrugated rubber from service respiratory equipment, a $\frac{1}{2}$-in. thickness of felt, balsa wood, and combinations of these.

While the tool was idling, it was possible to check the speeds with a simple revolution counter ; while it was working it was necessary to approximate by using a " Strobotac " meter, relying on the stroboscopic effect of an intermittent beam of light. It was found that the motor was slowed during grinding operations, and that nothing like a steady speed can be maintained in practice, though as far as possible it was kept steady during the taking of the readings. Degrees of out-of-truth of the spindle were measured by a standard meter, reading to a thousandth of an inch. On advice from the operator we confined our studies to one speed for each " head," because he said that each had its optimum speed and should not be worked at any other.

Comparisons were next made between methods A, B, and C, for working on the same steel casting. It was necessary not only to polish the rough surface of a casting, but often to remove as much as $\frac{1}{4}$ in. of excess metal as well. Where the shape of a casting is perfectly circular the excess can be removed quite simply by turning on a lathe ; at the corners this is impossible—hence the three alternative methods. The tool used in method B (fig. 9) is driven by an electric motor in the handle and is heavy, so the tool is suspended on a counterbalance weight allowing for movement in all planes. The handles are relatively thick, the grip needs to be less powerful, and the tool gives the impression of vibrating less than the one used in method A. In method C (fig. 10) the workman holds the casting to the wheel. The physical exertion involved is considerable, as it weighs perhaps 50 lb. ; however, with practice the work can be done quickly and well. It must be emphasized that in this method of working a large casting is being applied to a

relatively small wheel; this is very different from the procedure described by Agate, Druett, and Tombleson (1946), where castings of seldom more than 1 to 2 lb. were pressed against large, coarse wheels with the production of much vibration. With the method now being described, the vibration appeared to be very slight.

Finally, the rotary air turbine tools were considered. These were of two types: first, a heavy portable grindstone similar to the electrically driven one used in method B at the aircraft works; secondly, a light, high-speed tool normally held in one hand, and used for fine polishing of metal parts. It was fitted with a small composition "head," and the tool, when idling, rotated at 60,000 r.p.m., but slowed considerably under a load. It was very similar to that described in Dart's and Peters' papers, though their machines revolved at some 25,000 r.p.m.

The Results Recorded from Rotating Tools

In interpreting the figures for rotating tools set out in Tables 3 and 5, certain difficulties are apparent. It is sometimes difficult to be certain which is the fundamental frequency due to shaft speed of the tool, for, as already explained, the motor was slowed up whilst grinding, and technical difficulties often prevented a count of the shaft speed at the moment when the record was being taken. By experience it has been possible to tell which "peak" figure in each of the tables is likely to indicate the fundamental vibration; it is usually a little below that calculated from the nominal speed of the tool. Secondly, when the vibration is slight the sensitivity of the apparatus must be high, so that interference from the alternating mains electricity supply may appear on the 50-cycles band, owing to the difficulty of earthing the apparatus effectively. Some of the values at 50 cycles in Tables 3 and 5 may, therefore, be untrue. Where this seems likely, particularly where there are no values visible for the harmonics derived from 50 cycles (which would otherwise be expected), the figure has been put in parentheses. The mains current by itself produced no harmonics above 50 cycles. Thirdly, it will be seen that there are often larger amplitudes at frequencies *below* the supposed shaft-speed fundamental. A likely explanation of this is that a slow periodicity is being set up, analogous to the periodicity set up if men march in step on a bridge. In this case it is not the tool vibrating alone, but a complex mechanical system made up of tool, muscles, and the bones and joints which are held rigid by these muscles. The aggregate mass of these tissues is usually larger than that of the tool; this is seldom the case with the larger piston-operated machines. It is very likely that this slow periodicity would alter according to the weight and physique of the operator. Unfortunately, we were unable to test this out experimentally. Whether the foregoing is the true explanation of the anomaly or not, the pick-up was nevertheless recording the vibration which was reaching the surface of the hands.

Table 3 compares the conditions encountered while investigating the rotary tool used in method A (fig. 8). Table 5 compares the other two methods B and C; it depicts the vibration set up from the very high-speed air-turbine tool (fig. 12), and also the extent to which vibrations travel up the arm. For ease of comparison, Tables 4 and 6 have been constructed from Tables 3 and 5, just in the same way as Table 2 was derived from Table 1, using "standard amplitudes." This time the greatest amplitude recorded has been included as well as the amplitude of the probable fundamental, and in brackets below each of these figures the frequency is shown. The highest point in the spectrum at which amplitudes of 1 mm., 0·1 mm., 10 μ, 1·0 μ, and 0·1 μ are still present is recorded, as in Table 2. In most cases the fundamental is at 125 cycles per second, and most information is obtained from comparing the sizes of the fundamentals at this frequency. Amplitudes of 1 mm. or more do not appear in any of the records from rotating tools, and from this point of view they compare very favourably with the extremely high amplitudes recorded from pneumatic hammers.

A: The Vibration Reaching Right and Left Hands.—Comparing columns 19 and 20, it will be seen that the left hand suffers much more than the right hand; the highest figure is over three times as high, and the fundamental is over twice as high, while amplitudes of a given size appear higher in the spectrum. Columns 22 and 25 show again that, when using the larger cutter on the duralumin block, the left hand absorbs much more vibration than the right hand, for, at the highest amplitude, which in this case is identical with the fundamental, the figure for the left is three times that for the right. The distribution at higher frequencies is, however, approximately the same. These two examples are but typical of many comparisons between right and left hands which we made in the course of the experiments; in all cases the left hand absorbed more than the right.

B: Comparison of Vibration Set Up by Different Tool "Heads."—Altogether records were made of more than 15 different types of "head." These consisted of buffs, grinding stones, mops, wire brushes, bristle brushes, and toothed cutters. Three examples have been selected, as these were in common use; the others are omitted, from consideration of space. In all cases the left hand is considered. Column 20 refers to a silicon carbide stone (fig. 13), $1\frac{3}{4}$ in. in diameter and $\frac{3}{4}$ in. deep, mounted on a $\frac{1}{4}$-in. spindle. This head is commonly used on steel with the tool running at top speed under load, that is, at approximately 7,500 r.p.m. Column 21 refers to a felt "bob," or "buff," 3 in. in diameter and $\frac{3}{4}$ in. deep, dressed with glue and emery (fig. 14); this is also used at top speed on steel, and gives a fine polish. Column 22

TABLE 3

THE VIBRATION FROM A ROTARY TOOL WITH FLEXIBLE DRIVE

Study	The vibration reaching right and left hand; also the effect of different working "heads"					Effect of out-of-truth of spindle (Thousandths of an inch)				Effect of degree of wear of cable (Operator's description of cable)				Effect of different absorbent materials Materials on the handpiece					
						±2	±9	±2	±9	"Good"	"Good"	"Bad"	"Worse"						
Working "head"	Silicon carbide stone 1¼ in. diam.		Felt polishing buff 3 in. diam.	Large-toothed cutter		Small-toothed cutter				None				Silicon carbide stone 1¼ in. diam.					
						Idling		Working		Idling									
Tool speed	High		High	Medium		High				High				High					
Metal worked on	Steel		Steel	Duralumin		None		Duralumin		None				Steel					
Absorbent material	None		None	None		None				None				None	Respirator tubing	Balsa wood	Sorbo rubber	Balsa and sorbo	Felt
Hand ..	Right	Left	Left	Left	Right	Left				Left				Left					
	Amplitude																		
Frequencies in cycles per second																			
40	—	—	—	440 μ	155 μ	—	58 μ	295 μ	205 μ	—	—	—	—	—	(330 μ)	—	141 μ	—	—
50	135 μ	365 μ	105 μ	700 ,,	*240* ,,	(115 μ)	156 ,,	210 ,,	270 ,,	(140 μ)	—	(95 μ)	—	365 μ	240 ,,	145 μ	125 ,,	140 μ	130 μ
64	—	420 ,,	—	168 ,,	41 ,,	—	23 ,,	84 ,,	205 ,,	—	—	—	—	420 ,,	330 ,,	100 ,,	115 ,,	130 ,,	125 ,,
80	—	180 ,,	—	152 ,,	38 ,,	—	13 ,,	60 ,,	136 ,,	—	—	—	—	180 ,,	185 ,,	108 ,,	95 ,,	100 ,,	98 ,,
100	10 ,,	100 ,,	31·5 ,,	155 ,,	39 ,,	—	10 ,,	46 ,,	38 ,,	—	55 μ	—	—	100 ,,	62 ,,	80 ,,	70 ,,	51 ,,	52 ,,
125	62 ,,	143 ,,	125 ,,	63 ,,	6·5 ,,	15 ,,	33 ,,	33 ,,	90 ,,	9·8 ,,	112 ,,	—	63 μ	*143* ,,	*94* ,,	*93* ,,	*92* ,,	*80* ,,	*65* ,,
160	15 ,,	51 ,,	33 ,,	43 ,,	3·9 ,,	8·8 ,,	22 ,,	21 ,,	57 ,,	9·4 ,,	13 ,,	—	94 ,,	51 ,,	47 ,,	45 ,,	43 ,,	35 ,,	24 ,,
200	—	37 ,,	6·3 ,,	24 ,,	2·5 ,,	—	2·4 ,,	10 ,,	20 ,,	—	—	—	36 ,,	37 ,,	37 ,,	23 ,,	19 ,,	15 ,,	19 ,,
250	4·7 ,,	28 ,,	7·3 ,,	24 ,,	4·8 ,,	—	1·3 ,,	8·8 ,,	12 ,,	—	3·1 ,,	—	9·0 ,,	26 ,,	24 ,,	56 ,,	28 ,,	22 ,,	24 ,,
320	1·1 ,,	20 ,,	2·7 ,,	20 ,,	4·6 ,,	1·1 ,,	—	5·7 ,,	8·9 ,,	—	—	—	19 ,,	20 ,,	9·7 ,,	32 ,,	12 ,,	9·6 ,,	13 ,,
400	1·1 ,,	8·2 ,,	—	9·6 ,,	2·4 ,,	0·6 ,,	—	3·9 ,,	5·5 ,,	1·0 ,,	—	—	5·1 ,,	8·2 ,,	2·6 ,,	14·5 ,,	2·9 ,,	2·3 ,,	4·1 ,,
500	1·1 ,,	3·7 ,,	—	3·6 ,,	1·7 ,,	0·9 ,,	0·5 ,,	2·1 ,,	1·7 ,,	0·4 ,,	—	—	2·9 ,,	3·7 ,,	1·0 ,,	6·0 ,,	1·4 ,,	0·7 ,,	1·7 ,,
640	1·5 ,,	2·6 ,,	—	2·4 ,,	1·5 ,,	0·7 ,,	0·6 ,,	1·6 ,,	2·2 ,,	0·5 ,,	0·6 ,,	—	2·3 ,,	2·6 ,,	0·6 ,,	4·6 ,,	0·5 ,,	0·4 ,,	1·4 ,,
800	1·6 ,,	2·0 ,,	—	1·9 ,,	1·3 ,,	0·7 ,,	0·4 ,,	1·1 ,,	2·4 ,,	0·2 ,,	0·3 ,,	0·2 ,,	1·3 ,,	2·0 ,,	trace	2·7 ,,	0·3 ,,	0·2 ,,	1·0 ,,
1,000	0·9 ,,	1·3 ,,	0·3 ,,	2·5 ,,	1·4 ,,	0·4 ,,	0·2 ,,	0·5 ,,	1·2 ,,	0·3 ,,	0·2 ,,	0·4 ,,	1·0 ,,	1·3 ,,	,,	1·2 ,,	—	0·2 ,,	0·6 ,,
1,250	0·5 ,,	1·1 ,,	0·3 ,,	2·3 ,,	1·0 ,,	0·3 ,,	0·2 ,,	0·4 ,,	0·8 ,,	0·4 ,,	0·3 ,,	0·7 ,,	0·9 ,,	1·1 ,,	—	0·4 ,,	—	—	0·3 ,,
1,600	0·4 ,,	1·2 ,,	0·2 ,,	0·7 ,,	0·4 ,,	0·2 ,,	0·1 ,,	0·2 ,,	0·5 ,,	0·2 ,,	0·2 ,,	0·5 ,,	0·6 ,,	1·2 ,,	—	0·1 ,,	—	—	0·1 ,,
2,000	0·3 ,,	1·4 ,,	0·1 ,,	0·3 ,,	0·2 ,,	0·1 ,,	trace	0·1 ,,	0·3 ,,	trace	0·1 ,,	0·4 ,,	0·4 ,,	1·4 ,,	—	—	—	—	—
2,500	0·1 ,,	0·9 ,,	trace	0·2 ,,	0·1 ,,	trace	,,	0·1 ,,	0·2 ,,	0·1 ,,	0·1 ,,	0·2 ,,	0·2 ,,	0·9 ,,	—	—	—	—	—
3,200	trace	0·2 ,,	,,	0·1 ,,	0·2 ,,	,,	,,	trace	0·2 ,,	trace	trace	trace	0·1 ,,	0·2 ,,	—	—	—	—	—
4,000	,,	0·1 ,,	,,	0·1 ,,	trace	,,	,,	,,	0·1 ,,	—	—	,,	—	0·1 ,,	—	—	—	—	—
5,000	,,	trace	,,	trace	,,	,,	,,	,,	trace	trace	—	,,	—	trace	—	—	—	—	—
6,400	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	—	,,	—	,,	—	—	—	—	—
8,000	,,	,,	,,	,,	,,	—	,,	,,	,,	,,	—	,,	—	,,	—	—	—	—	—
10,000	,,	,,	,,	,,	,,	—	,,	,,	,,	,,	—	,,	—	,,	—	—	—	—	—
12,500	,,	,,	,,	,,	,,	—	,,	,,	,,	,,	—	,,	—	,,	—	—	—	—	—
16,000	,,	,,	,,	,,	,,	—	,,	,,	,,	,,	—	,,	—	,,	—	—	—	—	—
Col. No.	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37

TABLE 4

THE VIBRATION FROM A ROTARY TOOL WITH FLEXIBLE DRIVE. COMPILED FROM THE DATA OF TABLE 3

Study	Vibration reaching right and left hand; also the effect of different heads—while working					Effect of out-of-truth of spindle				Effect of degree of wear of cable				Effect of different absorbent materials					
"Head"	Silicon carbide stone		Felt polishing buff	Large-toothed cutter		Small-toothed cutter—idling		Small-toothed cutter—working		No head, machine idling				Silicon carbide stone—working					
Conditions	Right hand	Left hand	Left hand	Left hand	Right hand	Thousandths of an inch out-of-truth				Operator's description of cable				Absorbent material					
						±2	±9	±2	±9	"Good"	"Good"	"Bad"	"Worst"	None	Respirator tubing	Balsa wood	Sorbo rubber	Balsa and rubber	Felt
Greatest amplitude (frequency)	135 μ (50 ∽)	420 μ (64 ∽)	125 μ (125 ∽)	700 μ (50 ∽)	240 μ (50 ∽)	115 μ (50 ∽)	156 μ (50 ∽)	295 μ (40 ∽)	270 μ (50 ∽)	140 μ (50 ∽)	112 μ (125 ∽)	95 μ (50 ∽)	94 μ (160 ∽)	420 μ (64 ∽)	390 μ (64 ∽)	145 μ (50 ∽)	141 μ (40 ∽)	140 μ (50 ∽)	130 μ (50 ∽)
Amplitude of fundamental (frequency)	62 μ (125 ∽)	143 μ (125 ∽)	125 μ (125 ∽)	700 μ (50 ∽)	240 μ (50 ∽)	15 μ (125 ∽)	33 μ (125 ∽)	33 μ (125 ∽)	90 μ (125 ∽)	9·8 μ (125 ∽)	112 μ (125 ∽)	? (?)	63 μ (125 ∽)	143 μ (125 ∽)	94 μ (125 ∽)	93 μ (125 ∽)	92 μ (125 ∽)	80 μ (125 ∽)	65 μ (125 ∽)
Highest frequency (in cycles per second) at which the respective standard amplitudes are present																			
Standard Amplitude 1·0 mm. ..	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Standard Amplitude 100 μ	50	125	125	125	64	(50)	50	64	125	(50)	125	(50)	160	125	100	125	80	80	80
Standard Amplitude 10 „	160	600	200	400	125	160	200	200	320	160	160	—	400	400	320	500	320	320	320
Standard Amplitude 1·0 „	1,000	2,500	400	1,600	1,250	320	250	800	1,250	400	640	—	1,000	2,500	500	1,000	500	500	800
Standard Amplitude 0·1 „	2,500	4,000	2,000	4,000	3,200	2,000	1,600	2,500	4,000	2,500	2,500	2,500	3,200	4,000	800	1,000	800	1,000	1,600
Column No.	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37

TABLE 5

TOOL VIBRATIONS—VARIOUS STUDIES

Study	Comparison of methods A, B, C for grinding and polishing large steel castings for airscrews						Vibration from a high-speed rotary tool for fine polishing		Transmission of vibration up the arm			
Tool	Method A: flexible drive tool (see tables 3 and 4) with silicon carbide stone	Method B: electrically driven grindstone with motor incorporated in the handle		Method C: holding casting against belt-driven grinding wheel	Alternative tool for use with method B: air-driven portable grindstone				As for method A, using large cutting head on duralumin block (left arm			
Tool speed	approx. 7,500 r.p.m.	Nominally 4,300 r.p.m.			Nominally 5,400 r.p.m.		Approx. speed while idling 60,000 r.p.m.		Approx. 2,900 r.p.m.			
Special conditions	Left hand	Left hand	Right hand	Right *or* left hand	Left hand	Right hand	Right index finger, in "pencil-holding" grip at nose of tool	Right hand on pistol grip at back of tool	Recording from tool handpiece	Recording from skin of back of hand	Recording from skin over olecranon	Recording from skin over acromion
						Amplitude						
Frequencies (in cycles per second) 40	—	—	—	—	—	—	—	—	440 μ	162 μ	46 μ	—
50	365 μ	—	—	—	—	—	—	—	700 ,,	185 ,,	39 ,,	—
64	420 ,,	—	—	—	—	—	—	—	168 ,,	64 ,,	20 ,,	—
80	180 ,,	41 μ	49 μ	—	90 μ	—	—	—	152 ,,	105 ,,	13 ,,	—
100	100 ,,	—	—	—	31 ,,	—	—	—	155 ,,	150 ,,	15 ,,	—
125	*143* ,,	7·8 ,,	—	—	17 ,,	—	—	—	63 ,,	53 ,,	6·0 ,,	—
160	51 ,,	17·2 ,,	9·1 ,,	—	23 ,,	—	21 μ	—	43 ,,	34 ,,	5·2 ,,	—
200	37 ,,	13·5 ,,	17 ,,	—	11 ,,	15 μ	10 ,,	—	24 ,,	19 ,,	2·1 ,,	—
250	28 ,,	6·1 ,,	3·7 ,,	—	16 ,,	14 ,,	7·0 ,,	—	24 ,,	15 ,,	1·6 ,,	—
320	20 ,,	2·5 ,,	2·4 ,,	—	34 ,,	8·5 ,,	5·5 ,,	—	20 ,,	8·8 ,,	0·9 ,,	—
400	8·2 ,,	1·8 ,,	2·3 ,,	—	6·4 ,,	3·5 ,,	3·2 ,,	—	9·6 ,,	2·8 ,,	0·3 ,,	—
500	3·7 ,,	0·7 ,,	1·6 ,,	—	2·6 ,,	1·6 ,,	3·0 ,,	1·7 μ	3·6 ,,	1·0 ,,	trace	—
640	2·6 ,,	0·5 ,,	0·6 ,,	—	2·7 ,,	4·2 ,,	*4·0* ,,	*3·8* ,,	2·4 ,,	0·3 ,,	—	—
800	2·0 ,,	0·4 ,,	0·7 ,,	—	1·6 ,,	1·5 ,,	1·5 ,,	1·4 ,,	2·0 ,,	—	—	—
1,000	1·3 ,,	0·7 ,,	0·8 ,,	0·2 μ	2·0 ,,	2·7 ,,	0·8 ,,	0·8 ,,	2·5 ,,	0·1 ,,	—	—
1,250	1·1 ,,	0·6 ,,	0·6 ,,	0·9 ,,	0·9 ,,	3·6 ,,	0·7 ,,	0·5 ,,	2·3 ,,	trace	—	—
1,600	1·2 ,,	0·3 ,,	0·2 ,,	1·2 ,,	0·8 ,,	1·4 ,,	0·4 ,,	0·4 ,,	0·7 ,,	—	—	—
2,000	1·4 ,,	0·2 ,,	0·1 ,,	0·1 ,,	1·0 ,,	0·4 ,,	0·3 ,,	0·2 ,,	0·3 ,,	—	—	—
2,500	0·9 ,,	0·1 ,,	0·1 ,,	0·1 ,,	0·8 ,,	0·4 ,,	0·3 ,,	0·1 ,,	0·2 ,,	—	—	—
3,200	0·2 ,,	trace	trace	0·1 ,,	0·3 ,,	0·3 ,,	0·2 ,,	trace	0·1 ,,	—	—	—
4,000	0·1 ,,	—	—	—	0·1 ,,	0·1 ,,	0·1 ,,	,,	0·1 ,,	—	—	—
5,000	trace	—	—	—	trace	trace	0·2 ,,	,,	trace	—	—	—
6,400	,,	—	—	—	,,	,,	0·1 ,,	,,	,,	—	—	—
8,000	,,	—	—	—	,,	,,	0·1 ,,	,,	,,	—	—	—
10,000	,,	—	—	—	,,	,,	trace	,,	,,	—	—	—
12,500	,,	—	—	—	,,	,,	,,	,,	,,	—	—	—
16,000	,,	—	—	—	,,	,,	,,	,,	,,	—	—	—
Column No.	38	39	40	41	42	43	44	45	46	47	48	49

refers to a large pear-shaped steel cutter (fig. 15) with some 16 spiral cutting edges. This sort is used for cutting or "burring" excess metal from the duralumin block. It is used at medium speed, that is, at approximately 2,900 r.p.m. At this speed the teeth are least likely to get choked, and most power is available for cutting, for the operation is the heaviest for which this type of rotating tool is used. The fundamental will, in column 22, be seen coinciding with the highest amplitude at 50 cycles. When columns 20, 21, and 22 are compared, it will be seen that the felt bob causes least vibration. The cutter causes almost five times as much at the fundamental, although the frequency of that fundamental is lower. The silicon carbide stone occupies an intermediate position. The polishing buff causes less vibration at the higher end of the spectrum, but in this respect the stone and the cutter are nearly equal (cf. columns 20 and 22).

C: The Effect of Different Degrees of Out-of-Truth of the Spindle.—It is the usual practice, with the make of tool we were investigating, for the various heads to be mounted on a spindle $\frac{1}{4}$ in. in diameter. This spindle is $1\frac{1}{2}$ to 2 in. long, of which 1 to $1\frac{1}{2}$ in. projects from the chuck. As the spindle is so thin, it is easy to bend it by hitting the head of the tool inadvertently. Records were taken using a small cutter at high speed and recording from under the left hand. In the first case (columns 24 and 26) the spindle was adjusted to be as straight as possible and was, in fact, $\pm$ 2 thousandths of an inch out of truth. In the other case it was given a knock and was $\pm$ 9 thousandths of an inch out of truth (columns 25 and 27). Columns 24 and 25 refer to the tool while idling, and 26 and 27 to the tool while working. In each case it will be seen that the spindle which is $\pm$ 9 thousandths of an inch out of truth causes a considerably higher fundamental than the other, for, when idling, it is twice

TABLE 6

COMPILED FROM THE DATA OF TABLE 5

	Comparison of methods A, B, C, for grinding and polishing large steel castings for airscrew						Vibration from a high-speed rotary tool for fine polishing		Transmission of vibration up the arm			
Tool	Method A : silicon carbide stone	Method B : electrically driven tool		Method C	Alternative tool for method B : air-driven tool				As for method A : large cutting head on duralumin block			
Conditions	Left hand	Left hand	Right hand	Right *or* left hand	Left hand	Right hand	Pencil-holding grip, right index finger	Pistol grip, right hand	From hand-piece	From back of hand	From skin over olecranon	From skin over acromion
Greatest amplitude (frequency)	420 μ (64 ∿)	41 μ (80 ∿)	49 μ (80 ∿)	1·2 μ (1,600 ∿)	90 μ (80 ∿)	15 μ (200 ∿)	21 μ (160 ∿)	3·8 μ (640 ∿)	700 μ (50 ∿)	185 μ (50 ∿)	46 μ (40 ∿)	—
Amplitude of fundamental (frequency)	143 μ (125 ∿)	41 μ (80 ∿)	49 μ (80 ∿)	Fundamental not well defined	90 μ (80 ∿)	— (80 ∿)	4·0 μ (640 ∿)	3·8 μ (640 ∿)	700 μ (50 ∿)	185 μ (50 ∿)	39 μ (50 ∿)	—
Highest frequency (in cycles per second) at which the respective standard amplitudes are present												
Standard amplitude 1·0 mm.	—	—	—	—	—	—	—	—	—	—	—	—
Standard amplitude 100 μ	125	—	—	—	80	—	—	—	125	100	—	—
Standard amplitude 10 ,,	400	200	250	—	400	320	200	—	400	320	125	—
Standard amplitude 1·0 ,,	2,500	500	1,000	1,600	2,000	1,500	1,000	1,000	1,600	500	320	—
Standard amplitude 0·1 ,,	4,000	2,500	2,500	3,200	4,000	4,000	8,000	2,500	4,000	1,000	500	—
Column No. ..	38	39	40	41	42	43	44	45	46	47	48	49

as great, and when working it is three times as great. Moreover, while idling it causes high amplitudes at most of the low frequencies, and most closely resembles the state of affairs while any tool is being used for heavy work. While idling the "standard amplitudes" (Table 4) are present to about the same height in the spectrum, but, while working, a spindle which is out of truth causes the "standard amplitudes" to appear higher than they otherwise would. After it had been used for burring purposes, it was found that the spindle which had been originally ± 9 thousandths of an inch out of truth was now running more truly. A slender spindle, therefore, though liable to be bent when knocked, was fine enough to be straightened again by usage. An experienced man is normally in the habit of testing a spindle by feel and by eye, and adjusting it before use.

D : The Effects of Cables Worn to Varying Degrees.—Various motors and cables were used. Tool operators say that, as a tool gets older, the cable makes more noise and becomes hotter according to the degree of wear. A man could therefore say that a cable was "good" or "bad" by its sound or temperature while running. This criterion was the only one which could be used for the comparison of old and new, good and bad cables. The handpieces were held as usual, the crystal was under the left hand, and the tool was run at high speed, with no "head" in the chuck. Since the tool was idling it could be held with a light grip. This may explain the somewhat high values present in columns 28 to 31, values which would have been lower if the operator had had to exert his full muscular power.

It will be seen from columns 28 to 31 that there is little or no correlation between the vibration reaching the hand and the way in which a man describes his cable ; for instance, column 29, which refers to a "good" cable, shows a higher fundamental than column 31, which was described as the "worst possible" cable. The values at 50 cycles in columns 28 to 30 must be considered as suspect, for the reasons already given.

E : The Effect of Various Absorbent Materials Wrapped Around the Handpiece.—For this purpose the silicon carbide stone used for the initial experiment (column 20) was again used at high speed, working on steel, and records were taken from under the left hand, as follows :

(1) with no absorbent material (column 32 identical with column 20) ;

(2) with a thickness of corrugated, cloth-covered rubber, as used for service respirators (column 33) ;

(3) with a hollow cylinder of balsa wood split in two, shaped to fit the handpiece and strapped on, its thickness being $\frac{3}{8}$ in. (column 34) ;

(4) a thickness of $\frac{1}{2}$ in. sorbo sponge rubber (column 35) ;

(5) balsa wood laid on top of four narrow strips of the same $\frac{1}{2}$ in. sorbo rubber (column 36) ;

(6) a thickness of $\frac{1}{2}$ in. felt (column 37).

From these comparisons it will be seen that all the absorbent materials reduce the vibrations to some extent. The order of efficacy, when the amplitudes of the greatest

vibration and in particular the amplitudes at the fundamental frequency are considered, are as follows: felt, balsa wood over sorbo rubber, sorbo rubber alone, balsa wood alone, and respirator tubing. The effect of the last three mentioned is almost identical. At best these materials reduce the figures by $\frac{1}{3}$ to $\frac{1}{2}$, compared with the initial reading in column 32. At the higher frequencies the respirator tubing and sorbo rubber have some damping effect, and for this purpose the order of efficacy appears to be: respirator tubing or sorbo, balsa wood plus sorbo, felt, and balsa wood alone. It must be recorded that in all cases the operator said that the handle was made too bulky by the absorbent material, and that he was less comfortable and less able to work accurately.

Tables 5 and 6, derived from the same data, are divided into three sections showing the results of three distinct studies.

(*a*) *Comparison of the Vibrations from the Three Available Methods for Grinding and Polishing Large Steel Castings.*—To compare the methods, large rough steel castings for airscrew bosses or "barrels" were ground to remove excess of metal. The details of each have already been described. The tool with the flexible driving shaft, as used for method A (fig. 8) has been the subject of the detailed analyses in Tables 3 and 4, but a set of readings from the left hand using a $1\frac{3}{4}$-in. silicon carbide stone at approximately 7,500 r.p.m.—typical conditions for doing this work—is included (column 38) to make direct comparison easier. This column is identical with column 20 of Tables 3 and 4.

When method B (fig. 9) was being considered readings were taken from under both left and right hands (columns 39 and 40). The figures in each of these columns are very similar, but it is surprising to find that at the fundamental frequency a slightly larger amplitude was found for the right hand than for the left, although the left hand was on the front half of the handle nearest to the grinding wheel. This anomaly may perhaps be explained by the fact that the tool was suspended at its midpoint by a wire from the counterbalance weight, which might therefore act as a fulcrum and transmit an unusual quantity of vibration back to the right hand. This tool nominally worked at 4,300 r.p.m. driven by an electric motor, but the fundamental frequency of 80 cycles per second suggests that the real speed is nearer 4,800 r.p.m. An alternative tool which could be used for method B, that is, one worked by an air turbine at a nominal speed of 5,400 r.p.m. was also studied, and is the subject of columns 42 and 43, which deal with the right and left hand respectively. This tool was held in the same way, but without a counterbalance weight; it will be seen that the vibration reaching the left hand was much more than that reaching the right, but that for the former the size and range were very similar to columns 39 and 40.

In method C (fig. 10) the pick-up was placed directly on the steel casting under the right and left thumbs, but the two sets of readings are almost identical, and are included as one set in the tables (column 41).

Comparing the three methods it is easy to see that method C produces incomparably less vibration than method A. It cuts out all vibration whatsoever up to 800 cycles per second, and from 4,000 cycles upwards. Both hands are subjected equally to its very small vibration. It should be noted that the highest amplitude is 1·2 μ at 1,600 cycles, and this is the same value as for method A at this frequency; from other points of view, however, there is no comparison between them. When method B is considered it is apparent that its highest values of 41 to 49 μ at 80 cycles are only about one-fourth of the equivalent value for method A. Up to 64 cycles and above 3,200 cycles no vibration is encountered. Thus, method B is a marked improvement over A, but it is not so good as method C.

(*b*) *The Vibration from Very High-speed Rotary Tools.*—This tool (fig. 12) was similar to the one described by Dart (1946) but worked at the higher nominal speed of 60,000 r.p.m. when idling. It is likely that its speed dropped to about 38,000 r.p.m. during our experiments owing to being slowed by the friction, but this could not be accurately checked. The tool is $1\frac{1}{2}$ lb. in weight, and is easily held in the fingers of the right hand alone near the point, like a pencil; alternatively, it can be held with the right hand gripping at the back, pistol-grip fashion, and with the fingers of the left hand guiding the point. Our records were made from the right hand with both these grips, using the tool for polishing small pieces of steel. It will be seen that when they were at the point of the tool (column 44), the fingers absorbed much more than when they were on the pistol-grip (column 45). In the latter position the disturbance was negligible: in the former the fingers encountered no vibration below 160 cycles per second, but the value of 21 μ at this level is fairly large for such a frequency. In general, large amplitudes at low frequencies were not met with; nevertheless there is appreciable vibration at the top end of the frequency scale. It reaches at least to 8,000 cycles per second, that is, to a higher frequency than the vibration for any kind of rotary tool.

(*c*) *The Transmission of Vibration up the Arm.*—Tables 5 and 6 finally show a set of four records, columns 46 to 49, which were taken from various points up the left arm. They indicate what is likely to take place when any rotary type of tool is held in the hands. They were done on the suggestion that the damaging force might be acting more proximally than distally on the nerves or vessels. It is known already that a proximal lesion of an artery of the arm can give rise to intermittent local arterial spasm at the palm or fingers. The flexible drive tool was again used, under the worst conditions, namely—using a large-toothed cutter at medium speed while doing heavy work on a duralumin block. Column 46 records the state of affairs at the palm of the hand, and is identical with column 22 of Tables 3 and 4. When next the pick-up was strapped with adhesive tape to the skin on the back of the hand, the figures (column 47) were all much reduced and no vibration was in evidence above 1,600 cycles. From the skin over the olecranon the pick-up detected even less amplitude at each frequency, and the damping action of the tissues had more effect on the higher frequencies than on the lower, with the result that in column 48 the highest amplitude appears, not at 50 cycles as previously, but at 40 cycles. A pick-up placed

on the tip of the acromion detected no transmitted vibration whatever. It must be admitted that transmission of vibration across interfaces from tissue to tissue may affect its nature: there would be many such interfaces in recording vibration from far up a human arm, but it was outside the scope of our present work to consider this further. The results in columns 46 to 49 at best indicate a tendency.

Discussion

Study of the 49 columns makes it clear that the vibrations are complex in all cases, and that widely different methods of working can set up very similar conditions. Frequencies of the order of 1,000 cycles per second appear in nearly every column, and these seem to be related to the audible metallic "ring" of the metal of which a tool is made or of the metal being struck or ground. It is conducted back to the hands. Some simple experiments, such as striking a piece of metal on to which a pick-up had been placed, strengthen this view.

In order to detect any relationship between the characteristics of a vibration and the clinical effects caused by the tool in question, it is best to summarize those effects.

There is no certain evidence that Raynaud's phenomenon has resulted from using large road rippers, nor perhaps from somewhat lighter tools like coal picks. Extended inquiry might reveal occasional cases, but the numbers are probably not of practical significance. It has been suggested that navvying and the use of road rippers depend on casual labour, and that the men are, therefore, not exposed to hazard long enough for circulatory disturbances to appear. Rock drilling, by contrast, is far from a casual occupation, yet it leads to little trouble. These tools just mentioned are all large and used intermittently, and usually they work pointing downwards. Again, Raynaud's phenomenon has not yet been shown to result from using portable electric grindstones, as described above for method B. Those few men at the aircraft works who held the castings against the wheels as in method C likewise denied all knowledge of it. It has not occurred from the use of very light, high-speed tools. Finally, Hunter and others (1945) write of 12 men who used scaling hammers, and not one had contracted circulatory lesions, in spite of four of them having used such tools for over 20 years. This is surprising in view of the size of the vibration reaching the left hand (column 17); and if the phenomenon appears later in boiler scalers it must surely affect mainly the left hand. The lightness of the tool they use may be of significance, for the grip would therefore be light.

Positive evidence of Raynaud's phenomenon is reported from many quarters where the following tools are in use; (1) riveting hammers and "holding up" tools: (2) pneumatic chisels or chipping hammers, which are used for fettling castings, caulking, stone dressing, etc.; (3) portable rotary tools with a flexible drive (Telford and others, 1945); and (4) large grindstones against which small castings are being ground (Agate, Druett, and Tombleson, 1945).

Comparing the foregoing clinical facts with experimental results, it is evident that a plainly visible vibration of huge size and of frequency below 40 cycles per second (column 1) is not likely to be responsible, or road rippers would have been a source of trouble. Nor is it likely that high-frequency vibrations of 1,000 cycles upwards are responsible, because method C produces no symptoms, even though the amplitudes (see column 41) in its own range (around 1,600 cycles) are just as high as those from any others of the rotating types of tool. The field may perhaps be narrowed even further, because the very high-speed tool (columns 44 and 45) produces vibration from as low as 160 cycles upwards without evidence of Raynaud's phenomenon; but this argument must be accepted with caution, because if the amplitude at this frequency had been ten times as great (as it was in the case of the chipping hammers, see columns 2 to 7), there might then have been symptoms. Also, it must be remembered that Gerbis and others (1931) have suggested that vibration of 280 to 600 cycles per second caused vascular disturbances very rapidly, though we know nothing of the amplitudes involved. The evidence in general suggests that if any tool produces high amplitudes at the lower frequencies of, for example, 40 to 125 cycles per second, it is likely to produce Raynaud's phenomenon, particularly if it is in continuous use. Conversely, if a tool produces only high frequencies of, say, 600 cycles upwards, or it only produces small amplitudes (e.g. less than 100 μ) at the lower frequencies, it is *not* likely to cause Raynaud's phenomenon. Closer delineation is not yet possible, because there is still insufficient clinical evidence that tools which obey this last criterion have never produced the phenomenon. It is never safe to assume that there is no incidence of Raynaud's phenomenon from the use of a suspected tool until direct inquiry has been made. A man who suffers only slight disability may be reluctant to risk his livelihood by reporting his condition. A typical example of a tool which is a bad offender on clinical grounds is the flexibly driven rotary tool of method A with a large cutter mounted on its spindle (column 22). Experimentally this produces small vibrations at the high frequencies, none below 40 cycles per second, and

high amplitudes (152 to 700 μ) between 40 and 100 cycles.

The use of this last-mentioned tool requires further discussion. The heads of the tool are freely interchangeable. In practice it is common for one workman to do several operations in succession, changing the " head " each time. It is consequently difficult to incriminate any particular one, as most men have used all the heads at different times. In a series as yet unpublished, 300 men were seen by one of the authors working with this type of tool, and two-thirds exhibited Raynaud's phenomenon. The incidence of lesions was highest in the left hand for the right-handed workers. This agrees exactly with the experimental findings (columns 19 to 23), because the left hand always received most vibration. It has already been shown that the degree of wear in the cable has little bearing on the matter, but that if a spindle is out of centre the vibration is proportionally increased. It is likely that a robust spindle which could not be bent by a knock, and high-quality bearings in the handpiece, would reduce the disturbance. But conversely a slender spindle, set in the first place out of truth, may become trued by heavy use. We have watched an intelligent operator armed with a vice, a spanner, and chalk, set a spindle true in order to minimize his discomfort, but it takes time and patience to do this. The main defect of this tool appears to be that it is too light for heavy cutting duty. The heavier the handpiece, the less would it oscillate to the inevitable vibration set up ; the likelihood of this is demonstrated by the behaviour of heavy and light castings respectively, when ground by hand against a mounted grinding wheel. Moreover, the heavier a handpiece, the more of the work would be done by its weight and the less by the exertions and power of grip of the operator. The speed of this tool makes no appreciable difference, save that the frequency of the largest amplitude tends to fall as the speed falls ; the rest of the picture is little changed. The hardness of the metal worked upon is immaterial, as different cutters are used for different metals, and in this series the worst vibration resulted from cutting the duralumin, which is softer than steel.

The effect of absorbent coverings on the handpiece is limited. Their practical usefulness depends on their having small bulk in the hands of the operator and on their ability to stand wear and tear. It is certain that an increase in the thickness of the absorbent material does not have a proportional damping effect. Of the materials tried, a thickness of felt of $\frac{1}{8}$ in. reduced the amplitudes to $\frac{1}{2}$ or $\frac{1}{3}$ of their former values within the range of 50 to 125 cycles, but it was not so effective as some other materials in reducing higher frequencies. In this latter respect a layer of $\frac{1}{2}$ in. of sorbo sponge rubber or a sleeve of respirator tubing were about equally effective, but they were not very effective at the lower frequencies. Respirator tubing covered with cloth has proved itself to some extent capable of standing the wear and tear, but it is doubtful if any softer rubber would do so. If it is conceded that the most dangerous vibrations are at low frequencies and high amplitudes, felt coverings should be of more value than rubber, balsa wood, or respirator tubing.

Proof of the usefulness of any device to counter vibration can unfortunately only be obtained clinically if fresh workmen are employed and the work is done continuously under the new conditions for at least two years before the incidence of vascular disease is ascertained.

The preceding paragraphs refer to a tool, the use of which constitutes method A (fig. 8). It will be clear from columns 38 to 43 that method B (fig. 9) is an improvement, but that method C (fig. 10) is the method of choice if vibration is to be minimized. Where external surfaces of large castings are concerned, it is without doubt the most satisfactory method. But unfortunately it is more clumsy than other methods, and is not applicable to internal or complex surfaces, and certainly not to the burring of complex aero engine castings, for which method A seems to be almost indispensable. Nor is this method C satisfactory for polishing small castings of light weight, as the hazard under those circumstances has already been shown to be high. If metal castings could be mounted in lathes or milling machines and the burring and polishing were done purely by mechanical means, the problem of the vibration would be solved. Strenuous attempts to do this have already been made at more than one aircraft works.

Attention must turn again to the particular piston-operated pneumatic tools which have been shown to produce Raynaud's phenomenon. These are the chipping hammers and riveting hammers. These clearly produce intense vibration (see columns 2 to 7 and 11 to 16). Some of these records, unfortunately, do not show the size of the fundamental, but, by inference from the nearest harmonics, it can safely be assumed that those concerned must be of the order of 2 or 3 mm., and sometimes very much higher. Such figures are higher by far than any produced by rotating tools. Even though it appears from previous discussion that the frequencies below 40 cycles are little concerned with the pathological process, the values in columns 2 to 7 and 11 to 16 for the range 50 to 160

FIG. 1. (top, left)—Photograph from screen of double beam oscillograph, showing "trace" from the pickup superimposed on that of a regular 50-cycle mains alternating current.

FIG. 2. (bottom, left)—A road ripper, showing the pick-up strapped to one of the handles. It is standing upright in the hole which it has driven into a block of granite.

FIG. 3. (top, right)—A hand-operated rock drill.

FIG. 4. (bottom, right)—A coal pick.

FIG 5.—A large riveting hammer.

FIG. 6—A chipping hammer.

FIG. 7.—A scaling hammer.

FIG. 8.—Method A for grinding steel castings. A small rotary grinding wheel is mounted at the end of a handpiece. Power is supplied from a motor (not shown) by means of a flexible drive.

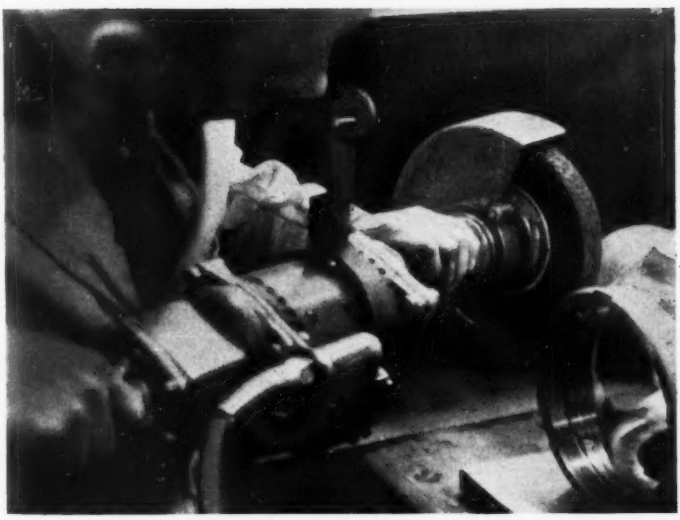


FIG. 9.—Method B for grinding steel castings. A portable grindstone, electrically driven by a motor, is incorporated in the handle. The weight is taken by a counter-balance weight.

FIG. 10.—Method C for grinding steel castings.

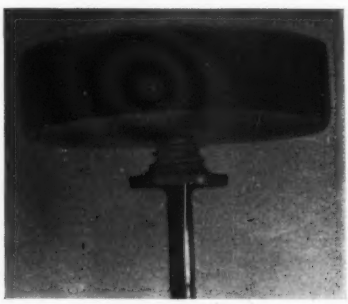
FIG. 11.—The grip typically used while grinding by method A. The handpiece shown here is covered by one of the experimental absorbent materials—a sleeve of cloth-covered respirator tubing made of corrugated rubber.

FIG. 12.—A light, portable polishing tool driven by an air turbine, and designed to rotate at 60,000 r.p.m. It is held like a pencil in the fingers of the right hand.

FIG. 14. (centre, right)—The 3-in. felt buff dressed with glue and emery, for use in method A.

FIG. 15. (bottom, right)—The large-toothed steel cutter, for use in method A.

FIG. 13.—The $1\frac{3}{4}$-in. silicon carbide grinding stone, for use in method A.



cycles are very high indeed. In all these columns it appears that the right hand is receiving more disturbance than the left. But many authors have stated that the left hand is the most affected by these tools. Hunter and others (1945) show that the left hand is more than twice as often affected as the right. This would appear to contradict the experimental evidence presented, but for the fact that, as has already been shown, the right hand receives a large component of vibration to and fro along the length of the tool, while the left receives the same component *across* the fingers, and also a secondary component at right angles to the first. In a sense, therefore, the left hand is receiving more than the right. These conditions only apply for a tool handled in the way in which riveting or chipping hammers are handled.

In the paper last quoted there is evidence to suggest that the greatest incidence of disease occurs when tools of 2,000 to 3,000 strokes per minute are used. We were unfortunately not in a position to compare tools of this range with any at higher and lower rates working on the same task. However, the vibration appears to be of the same complexity and about the same magnitude for all these tools, and from the figures it is difficult to conceive that their effects would be widely different in practice. The larger riveting hammer at 1,050 b.p.m., when used on hot rivets, seemed to produce a worse disturbance than the smaller at 1,700 b.p.m. On the other hand, the smallest chipping hammer at 6,000 b.p.m. caused much more vibration than the medium one at 3,500 b.p.m., when they were both used on the same piece of work. It appeared that this small hammer was being made to do heavier work than it was designed to do. As far as these hammers are concerned, it appears likely that the salient factor is not so much the tool speed as the heaviness of the work, expressed in terms of speed of working, exertion, and grip required. It may well be that the heaviest and most sustained work necessitates the use of tools at 2,000 to 3,000 b.p.m. When hot rivets are compared with cold, the harder cold metal causes a slight increase of disturbance for the right hand; but rivets of this size would never be hammered in the cold.

The high-speed tool we examined (columns 44 and 45) had a nominal speed of 60,000 r.p.m., which is up to six times that of the tools described by Dart (1946), but, in size, principle, and method of operation, they were similar. He states that such tools operate at 10,000 to 50,000 r.p.m.; though ours was even faster, the variations in speed during normal working were striking. Our tool running at an estimated working speed of 38,400 r.p.m. produced an amplitude of 4 μ at the fundamental of 640 cycles per second, and its highest amplitude was 21 μ at 160 cycles. Dart writes of a vibration of 80 μ at 12,000 per minute, or 200 cycles per second, though whether this is the fundamental is not made clear. If, instead, it represents the highest recorded amplitude, his values are higher than ours but the frequency is comparable. Such a tool does not produce Raynaud's phenomenon, neither does it produce any vibration below 160 cycles per second. Dart states that of his total of 1,000 workers using this tool, there were some 11 per cent. with symptoms of the less objective type, namely, pain, numbness and stiffness, and signs of swelling, erythema, or cyanosis. There may, therefore, be some relationship between such a distinct syndrome and this type of vibration, for here in column 44 the rate for the main amplitudes is 160 cycles or above, with a spectrum reaching almost to the upper recordable limit. There is not a similar set of figures relating to the hand under normal working conditions anywhere else in our records. The vibration detected while using method C is of high frequency, true enough, but the amplitudes are all very small, and no comparable clinical syndrome has yet been shown to have resulted from using method C.

Dart lays some stress on the details of the grip of the fingers. He shows that the " pencil grip " may be the worst, and columns 44 and 45 demonstrate the difference between the disturbance produced while using the pencil grip and that while guiding the tool from behind. In our experience of grinding operations, an operator seemed often to change his grip, and it would have been impossible to incriminate any one grip in particular.

Negative Clinical Findings from a High-speed Tool.—An opportunity occurred at one stage in the work to put direct questions to ten people using a tool of the light, high-speed type. It had a nominal speed of 30,000 r.p.m. All the operatives, nine women and one man, denied any symptoms whatever that they could have attributed to their work. The relevant details are set out in Table 7.

The series was collected in the North of England in the spring of 1945. The average duration of their employment at this work without symptoms was 2 years 8 months. Dart, however, writes that in a series of 109 cases with symptoms, the average duration of employment had been only 8 months, with a range of from 1 week to 30 months. Though our series is small and concerns a young age group, it is surprising that not a single case comparable with Dart's was discovered, especially as the mean of the working periods was longer than the longest working period he had recorded. If

TABLE 7

TEN WORKERS WHO WORKED WITH A LIGHT HIGH-SPEED TOOL WITHOUT VASCULAR DISTURBANCES

Worker No.	Age	Employed with this tool for—
1 (male)	31 years	5 years
2 (female)	23 ,,	4 ,,
3 ,,	38 ,,	4 ,,
4 ,,	21 ,,	3 ,,
5 ,,	26 ,,	3 ,,
6 ,,	21 ,,	2¾ ,,
7 ,,	25 ,,	2 ,,
8 ,,	26 ,,	1 year
9 ,,	21 ,,	1 ,,
10 ,,	36 ,,	9 months

an attempt should be made to reduce the vibration from light high-speed tools, our experiments suggest that a sleeve of sorbo sponge rubber or respirator tubing would probably be the most effective, because it is high frequency vibration of small amplitude which has to be combated.

Practical Applications

The following generalizations and suggestions for reducing harmful vibrations now seem to be justified.

1. Grinding, machining, and hammering processes should be as fully mechanized as possible.

2. Since portable tools are in many circumstances indispensable, the manufacturers of those tools should be urged to concentrate on modifications of design which will lessen vibration. They have in some cases shown themselves very willing to do so.

3. Vibrating tools should not be used on operations which are heavier than those for which they were designed.

4. The heavier a portable tool is in relation to the work in hand, the less it will vibrate.

Concerning Pneumatic Drills, Picks, Hammers, and Chisels

5. Methods might be sought for reducing the backwards thrust by bracing the tools against solid objects, or by mounting them on adjustable rigid beams. An adjustable portable stand is already made on which the weight of drilling tools can be taken for horizontal boring.

6. The weight of the tool might in some cases be taken by a suspended counterbalance weight. In some repetitive work this practice is already followed, as in locomotive boiler stay drilling and tapping.

7. The thrust might be divided to be taken on to both hands, or on to the thigh muscles, by extra handles.

8. Absorbent materials are not likely to be of much value.

Concerning Methods of Grinding

9. Light-weight tools with a flexible drive seem, on medical grounds, to be best avoided except for very light operations. There must be many conditions, however, in which their use is necessary.

10. The grinding method of choice, apart from any in which neither the work nor the tool is touched by hand, is that of holding castings against grindstones on fixed mountings, but this is true only for larger castings. Failing this method, the heavier the portable grinding equipment the better.

11. If tools with a flexible drive have to be used, they should be of heavier pattern than those at present manufactured, the spindle should be thick and rigid, and should run true on first-class bearings. The operator should be taught to correct a spindle which is not properly centred, and should be given the necessary tools to do this. He might with advantage alternate periods of heavy grinding with lighter polishing work.

12. Absorbent materials on the handpieces of tools with a flexible drive may be expected to have limited value only; if they are used, those which absorb low frequencies will probably be most effective (*vide supra*).

13. For light, high-speed tools, absorbent materials which reduce the higher frequencies should be the most effective (*vide supra*).

Much of this work suggests, in conclusion, that the incidence of vascular disturbances does not depend solely on the character of the vibration. Grip is another likely factor in the production of local arterial spasm, but it could not be investigated by the present method. The most likely combination of provocative circumstances is vibration of fairly low frequency and large amplitude, coupled with the need to use an excessive grip over long periods. Further work on this aspect of the ætiology would be welcome.

Summary

Two clinical pictures which result from the use of vibrating tools are reviewed, with particular reference to the speeds of the tools, and the vibration frequencies which have hitherto been considered harmful.

In the first clinical picture, Raynaud's phenomenon has been the predominant disorder, and it has arisen after the use of pneumatic hammers, from portable rotary grinding tools, and from grinding small metal parts by hand. In the second, the features are pain, numbness, stiffness, and swelling of the fingers, and the portable tool involved is used for light metal polishing and rotates at a high speed.

The complexity of vibrations from tools is discussed. Electrical methods of analysis of these, in terms of frequency and amplitude of the harmonics, have been used to take records from tools working under different conditions. Such records were taken from the following piston-operated tools: road rippers, pneumatic chisels (chipping hammers), coal picks, rock drills, riveting hammers, and scaling hammers. Others were made of the vibration set up in the use of a portable grinding tool driven by flexible drive. The effect of the work on right and left hands, the effect of various cutting and grinding "heads," degrees of out of truth, degrees of wear in the flexible drive, and of absorbent protective materials were determined. Three alternative methods for doing the same piece of grinding work were compared. The special characteristics of vibration from high-speed rotary tools responsible for the second clinical picture were demonstrated. Finally, a study was made of the transmission of vibrations up the arm.

By comparison with clinical data it appears probable that vibrations of large amplitude between the frequencies of about 40 and 125 cycles per second are concerned in producing Raynaud's phenomenon, and that tools which show none below 600 cycles are not likely to produce it. The lower limit may be below this, but the clinical evidence is still too scanty to allow of closer delineation. With rotary tools of the type with a flexible drive, the left hand is subjected to most vibration, toothed metal cutters cause most disturbance, and the vibration is greater the more out-of-true the heads are set. A worn flexible cable appears to have little aggravating effect. Of the absorbent materials tested, felt is probably the most effective for such a tool, though none has a very pronounced usefulness.

When the three alternative grinding methods are compared, that of holding castings against a grindstone mounted on a bench is likely to be harmless, provided that the castings are relatively large.

Very high-speed rotary tools produce a different type of vibration, namely, of relatively small amplitude and of high frequency, none being present below 160 cycles per second. This may account for the differences in clinical findings which have been observed from the use of such tools. A small series of ten workers is discussed, who complained of no symptoms whatever after they had used this type of tool for an appreciable time; this conflicts with the experience of other writers.

Piston-operated tools all seem to produce similar vibration spectra, and it is probable that pathological effects bear more relation to the type, arduousness, and uninterrupted nature of the work done than they do to a definite range of supposedly hazardous tool speeds. A number of suggestions is put forward for reducing harmful vibrations. The possible relationship between vascular lesions and the strength of the grip could not be studied by the methods used in these experiments.

We wish to thank the Director of the Department, Dr. Donald Hunter, for continued advice and encouragement, and Dr. Kenneth Perry for his valuable help. We are indebted to the Controller of the Post Office Research Station who lent the acoustic spectrometer, and to the Gramophone Company Ltd. for the loan of other apparatus. We gratefully acknowledge the kindness and unstinted help of Dr. D. R. Thompson of the De Havilland Aircraft Co., Ltd., and the co-operation of the management and scientific staff of that company. It is a pleasure to record our gratitude for the enthusiasm of Mr. A. Treve Holman and for the help he and the staff of Messrs. Holman Brothers Ltd. gave us. Our thanks are particularly due for the patience of Mr. Robinson and others who operated the tools during the experiments, and to Miss M. F. Daniel for technical help.

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EFFECTS OF CLIMATIC EXTREMES

BY

MACDONALD CRITCHLEY

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The time is opportune for a re-discussion of the important problem of climate and human survival. During the recent war it was made plain to us that campaigning might take place in all parts of the globe and in climates which were as varied as they were extreme. It was not merely a question of carrying on a desultory or sedentary existence in inauspicious environments, but of maintaining the highest possible vigilance and efficiency while engaged in heavy manual work. We are reminded of the statement of Burot and Legrand, that " in the tropics the soldier is always in campaign ; if not against the enemy, at least against the climate." And again of the Roman axiom, " In the land of the enemy, beware of the country, the water, and the time of the day."

With the return of peace the future of the Empire —whether it is to be developed or neglected—will arise. Search for new sources of raw materials, transpolar air-routes, and development of naval bases in the tropics will necessitate efforts to make remote regions more habitable and more endurable. The question must soon be faced whether the torrid and the frigid zones can ever be made suitable for the maintenance, not only of a sedentary official caste of white settlers, but of commerce, trading, and industry at the hands of non-indigenous personnel. As Ripley put it, " To tolerate a climate is one thing : to become independent of it is quite another." For the past half century, at least, certain geographers, anthropologists, and biologists have discussed the matter of the future of the white race in regions where the climate is unfavourable, more especially in the tropics. Polar territories have not received so much attention. Many of these papers have been thoughtful and provocative contributions, but unfortunately the views expressed have largely cancelled each other out, so that the reader ultimately finds himself alive to the difficulties of a complex problem, but bereft in his own mind of any clear convictions or opinions.

As far as the tropics are concerned, there are broadly two opposing views : (1) that the coloured races alone are capable of consistent survival ; and (2) that in certain circumstances it is by no means impossible for a white civilization to flourish in such regions. The arguments adduced by those who are dubious of the future of the whites in the tropics may be summarized as follows.

1. Since Hippocrates, it is believed that there is an intimate connexion between climate, geographical configuration, and the personality of the indigenes. Hence colonization is handicapped. Uniform climates are non-stimulating, especially hot humid climates.

2. In the tropics, coloured peoples have certain physical advantages over white newcomers, for example : their protective pigment ; more efficient sweat apparatus and a different distribution of apocrine to eccrine sweat glands ; centuries of acclimatization, with survival of the more robust specimens ; and individual habits of work and conduct which are more appropriate to the environment. White folk are disadvantageously placed in these respects, while Mediterranean peoples are in an intermediate position, whether because of their colouring or because of their intermingling with native blood.

3. Ubiquitous tropical disease constitutes a hazard which reduces the expectation of life and considerably influences vital statistics.

4. A psychological, later a physiological, deterioration of white newcomers is the rule after about two or three years.

5. Acclimatization is virtually an impossibility in colonizers, despite pious hopes to the contrary.

6. Even in the rare cases where the white settler does not suffer any mental or physical impairment, his children will not be endowed with the robustness of those born in temperate countries.

7. The fertility of white races actually decreases in the tropics.

8. Hence, after a period of colonization the colonizers are represented either by a small aristocratic caste of newcomers, or else by an inept " poor white " community of old-timers.

9. History has always demonstrated a steady march of civilization to the north and to the west—the " cold-ward course of progress."

Without necessarily trying to counter directly the arguments of their opponents, those who are optimistic about the future of the white races in the tropics put forward reasons of their own. Chief among them may be mentioned the following.

1. It is too sweeping a statement to assert that the tropics are unpropitious for white races. Desert regions certainly can be made habitable, and the overwhelming success of the colonization of the northern territories of Australia can be quoted. It is perhaps safer to assert that jungle areas rather than desert may not support a healthy white stock.

2. Most of the handicaps of tropical life arise from the numerous diseases which flourish in such environments. Such are theoretically preventible, and indeed even within the last two years the newer insecticides and insect-repellents have put an entirely new complexion on the problem. If tropical disease were stamped out, then tropical areas would be fit for habitation.

3. Civilized man is able to erect barriers between himself and his environment. Or, to quote Eijkman, "If he cannot be made fit for the climate, then make the climate fit for him." The assistance which might be afforded by air-conditioning, and by scientific housing and plumbing, has not yet been explored fully.

4. But little attempt so far has been made to select scientifically those best fitted for tropical residence, and to reject the unsuitable. Hitherto, merely a very strict medical examination has been relied on. Such may perhaps not be the ideal screening procedure.

5. When white and negro labourers are put to the same job, the former excel in productive capacity.

6. Intermarriage of white with indigenous stock may conceivably be the correct biological answer to the problem. It may be argued that the alleged drawbacks of Eurasian or mulatto or mestizo populations are examples of pure prejudice and divorced from scientific support.

It will be noted that most of the arguments, for and against, concern the hotter regions; cold climates have come in for far less discussion in this connexion.

It is also clear to any outside critic that most of the arguments on both sides of the controversy are matters of opinion. Facts are sadly lacking in this problem, and emotion and prejudice appear to intrude too much into the province of what should be a purely objective and scientific debate. Obviously we do not know enough about the subject. Equally clear is the fact that the study is a worthy one, which might repay with high dividends the labour and cost of research.

Linked to the primary question, "Can whites survive in the tropics and polar regions?" there are two very important supplementary questions: (1) to what extent is human efficiency, physical and mental, affected by working or living in atmospheres of undue heat or cold? and (2) how can the efficiency of such individuals be enhanced, in these adverse circumstances?

Measurements of Environmental Conditions

An essential preliminary to any scientific study of the effect of climatic extremes is the exact measurement of environmental conditions. Simple thermometric readings are not enough, for we also require to know (1) the extent to which the surrounding air is in movement; (2) the amount of water vapour which is present in the atmosphere; and (3) the extent to which radiation of warmth or cold occurs from the environment. There may of course be other physical, chemical, or electrical variants which are significant, but at present we have but little inkling of these.

According to Bedford (1937 a, b; 1946), the main single or combined environmental measurements are the following:

Air Temperature.—The ordinary dry-bulb mercury thermometer is widely used. Its value can be enhanced (*a*) if the bulb is covered by bright metal foil (to reflect radiation), or (*b*) if the thermometer is whirled through the air (as in the sling psychrometer).*

Humidity.—This is usually measured by noticing the difference between the dry-bulb and the wet-bulb thermometer reading. For more accurate work a whirling instrument, or an Assmann hygrometer, should be used. There is also a direct reading instrument, operated by the expansion or contraction of a hair. Humidity is expressed either as absolute humidity or relative humidity.

Air Velocity.—Anemometers of the rotating vane or propeller type are used to record the speed of unidirectional air currents. For low air-velocities, and for measuring the combined air-movement of eddies, the kata thermometer is valuable.

Radiant Heat.—Measurements of radiant heat from a localized source are best carried out by an electrical thermopile recorded with a galvanometer.

Kata-thermometry.—Originally introduced by Hill as a measure of body cooling, this instrument has since proved to possess other useful qualities which are less open to criticism. Thus, as Hill and others (1916) showed, it is a valuable method for estimating the velocity of air movement even when the velocities concerned are extremely low. The kata thermometer can be used "dry" or "wet." The former was regarded originally as a means of estimating the sum of the effect of the air temperature and the velocity of its motion in cooling an instrument whose temperature is about that

* According to Bedford, calculation of the total heat of the air, expressed in British thermal units per pound of dry air, is of great practical importance, especially in ventilation engineering. It expresses the heat that would be given up by the air if it were cooled to 32° F. and all the moisture condensed out. The number of grains of water vapour per pound of dry air (g) is determined from the ordinary psychrometric chart. Then, from a table, the formula $H - h_a + ghw$ will supply the desired figure: H being the total heat of that weight of moist air which contains one pound of dry air; h_a being the heat contained in one grain of water vapour.

of the human body. It is the instrument of choice in environments where the skin remains dry. The wet kata thermometer allows for the effect of evaporation, to temperature difference and wind. It was believed to give a better index of the true state of affairs in the tropics, where the subject is lightly clad and sweating freely. For the measurement of air velocities, the dry kata is the one ordinarily employed. Special high-temperature kata thermometers are devised for the study of air velocities in specially hot atmospheres, such as boiler- and engine-rooms, and deep mines.

The valuable papers of Hill and others (1916), Hill (1920), Angus (1924), Vernon and others (1926), and especially Bedford (1937 a, b ; 1946) should be consulted for details and criticisms of kata-thermometry. One of the earliest and best field studies of the use of the kata thermometer, namely at sea in the tropics, was made by Dudley (1928).

Globe Thermometer.—Vernon devised this instrument as a means of studying the effect of temperature upon human comfort where there exists a source of radiant heat. It consists merely of a dry mercury bulb thermometer inserted within a 6-inch hollow sphere coated with black matt paint. Equilibrium with the environment is reached in about twenty minutes, and the result is an integrated measure of the radiation impinging upon the surface of the sphere (cooling due to air movement must be allowed for). This device has been used a good deal of late in H.M. ships, where unilateral or multilateral sources of radiant heat are commonly encountered and so interfere with the accuracy of ordinary psychrometric readings (see Bedford, 1946).

Effective Temperature.—This indicates the temperature of still air saturated with water vapour, in which an equivalent sensation of warmth was experienced in a series of tests made by Houghten and Yaglou (1923). It is a combined measurement which embraces temperature, humidity, and air movement. This measure is one which has of late been used widely in ventilation practice, more particularly in America. Undoubtedly it possesses many advantages, but it nevertheless is not free from certain serious drawbacks. It fails to account for human acclimatization : it is probably inaccurate at the higher velocities of air movement and at the upper ranges of temperature ; it is not applicable when radiant heat is a factor ; it does not cater for subjects engaged in manual work.

Corrected Effective Temperature.—To overcome the error introduced by radiation, Bedford has suggested the use of Vernon's globe thermometer in the nomograms, to replace the ordinary dry-bulb temperature. The calculations are then made as usual, and the final figure is spoken of as CET or the "corrected effective temperature" (see Bedford, 1946). When these nomograms are not available, the mean temperature can be calculated from the following formula, where t_s, t_g, and t_a are the temperatures of the surroundings, the globe thermometer reading, and the air temperature in degrees Fahrenheit, and where v is the air velocity in feet per minute :

$$(t_s+4bo)^4\times 10^{-9}=(t_g+4bo)^4\times 10^{-9}+0{\cdot}1028\sqrt{v(t_g-t_a)}$$

Resultant Temperature.—This is another combined measurement which aims at allowing for radiation. Devised by Missenard (1933), with the aid of a function termed the "fictitious air-velocity," allowance is made for radiation, exercise, and clothing. It would appear that this omnibus measure—very promising in its practical application—is not yet out of the experimental stage.

Equivalent Warmth.—This is another combined measure devised by Bedford and based upon the subjective sensations of a large series of factory workers. Based upon about 2,600 so-called "comfort votes," it was found that the equivalent warmth scale was the best index. It depends upon the rate of heat-loss from an instrument named the "eupathcoscope," a heated cylinder 22 in. $\times$ 7½ in.

Thermal Comfort

Freedom from excessive temperature levels, from abrupt changes from one level to another, from unduly high humidity, and from inordinate wind velocities, predispose to a state of personal thermal comfort. The subject concerned must himself be adequately clad, yet not too heavily so. He must not be generating heat to excess, as, for example, from pyrexia or from bodily exercise ; nor must he be losing heat to an undue degree by evaporation of sweat, by convection, or by radiation. This "comfort" state is largely a negative one, comprising a freedom from the impingement upon the sensorium of thermal stimuli. Many attempts have been made to draw up the personal and environmental conditions necessary to produce such a comfort state. In their original work upon the effective temperature scale, Houghten and Yaglou (1923) plotted an area upon their nomogram, between the limits of which lay a so-called "comfort zone." This extended between the minimum and maximum of 57° and 63° F. But, of course, racial factors, habit, and acclimatization play an important role, and it does not follow that the original subjects tested, who were Americans, have the same standards of atmospheric comfort that we would recognize in this country.

Bedford's study of the requirements for satisfactory ventilation and heating laid down the following desiderata : (1) a suitable degree of warmth ; (2) the air at head level should not be appreciably warmer than that near the floor ; and the heads of the occupants should not be exposed to excessive radiant heat ; (3) the air should be moving rather than still, and variable in its rate of movement rather than uniform and monotonous, but there should be no local draughts ; (4) the walls should be warmer than the air ; and (5) the fresh air supply should be sufficient to keep the room free from odours.

Turning to actual figures for the foregoing stipulations, Bedford defines a suitable comfort zone as one in which

70 per cent. at least of their subjects were quite comfortable. This zone is represented by an equivalent temperature of 58° to 66° F.; a globe thermometer reading of 62° to 68° F.; or an effective temperature of 57° to 63° F. Standards of "fresh air" supply, considered as a component of a comfort zone, are more difficult to fix. Removal of odours is a traditional touchstone. The early figure of 20 cubic feet/minute/person was raised to 50 cubic feet/minute/person by Chaumont (1875). Recent work has shown that it is necessary when discussing standards of fresh air supply, to take account of the size of the compartment under consideration and the number of occupants. As the space per person decreases, the ventilation requirement increases. A small room requires more air circulation than a large one, for the same number of persons. In ordinary circumstances and conditions 17 to 20 cubic feet/minute/person is enough, that is, a change of 1,000 to 1,200 cubic feet an hour.

In H.M. ships special conditions of occupancy occur, and the unavoidable crowding, the accumulation of body odours, and the risk of airborne infections, necessitate special standards. The 1910 conference on tubercle in the Royal Navy led to an Admiralty Committee on Ventilation which enacted (in 1914) a minimum supply of 3,000 cubic feet/person/hour. As an index of adequacy of air change it was laid down that samples of air from any living-space must always contain less than 0·12 per cent. of carbon dioxide. A second Ventilation Commission (1937) covered the standards to 1,500 cubic feet (2,000 cubic feet if possible)/person/hour, that is, a change of air every five minutes.

In the U.S. Navy, during the war, ventilation was stepped up, as much as 300 per cent. in some cases. The new requirements of the Bureau of Ships were a minumum supply of 30 cubic feet/man/minute for sleeping and working spaces, and 20 cubic feet/man/minute for messing spaces. (In U.S. ships the ratings do not eat and sleep in the same compartment.) In general, however, levels as high as 40 to 60 cubic feet/man/minute were often achieved.

It is interesting to note, on reading the history of marine and civil ventilation, that the standards varied as the emphasis passed from one atmospheric constituent to another. The earlier engineers and surgeons were preoccupied with odours arising from stagnant water in the bilges, and vitiation of the air from animal exhalations and various fumes and gases.* Later they began to speak in terms of carbon dioxide. Only to a lesser degree was humidity considered, while the environmental temperature was rarely, if ever, discussed. Perhaps the wheel has turned nearly full cycle, with the present interest in the risk of droplet infections, especially from atmospheres artificially ventilated with re-circulating air.

In computing sensorial effects of differing environmental states we have in the past been handicapped by the lack of adequate standards. Crowden and Lee (1940) have largely met this objection by their "thermal sensations scales," which attempt to mark the humidity and temperature levels in terms of the subjective sensations of observers at rest or at least engaged only in light work. The scales are shown in Table 1.

TABLE 1
THERMAL SENSATION SCALES

Heat sensation scale (Hot and cold sensations)		Humidity sensation scale (Moist and dry sensations)	
Sensation	Index	Sensation	Index
Unbearably hot ..	+7	Unbearably moist	+7
Much too hot ..	+6	Much too moist ..	+6*
Too hot	+5	Too moist ..	+5†
Hot	+4	Moist	+4‡
Too warm ..	+3	Too humid ..	+3
Warm	+2	Humid	+2
Comfortably warm	+1	Comfortably humid ..	+1
Neutral	0	Neutral	0
Comfortably cool	−1	Comfortably dry	−1
Cool	−2	Dry	−2
Too cool	−3	Too dry	−3
Cold	−4	Parched	−4
Too cold	−5	Too parched ..	−5
Much too cold ..	−6	Much too parched	−6
Unbearably cold ..	−7	Unbearably parched ..	−7

* Sweat dripping off.
† Conscious sweating.
‡ Skin moist.

The question of optimum environmental conditions for rest and work leads naturally to the consideration of the most desirable type of climate. Later the problem is discussed more fully, but it is worth while at this point to mention Brunt's (1943) conception of an ideal climate. In his opinion it is desirable for a lightly clothed man to walk at four miles an hour in the sunshine without sweating, and to sit in the sunshine, or stand or sit in the shade indoors and engaged in light work, without shivering. With humidity at 60 per cent., the temperature which complies with these conditions would be between 66 and 68° F. Markham (1942) also earlier laid it down that an ideal climate entails a mean temperature of no more than 75° F. in the hottest month of the year, and in the coldest month a mean temperature not below freezing point. The virtues of a variable over a uniform climate are considered later.

* An interesting contemporary account of the conditions in the sick bay of *H.M.S. Thunder* can be read in Smollett's description. "About fifty miserable distempered wretches, suspended in rows, so huddled one upon another, that not more than fifteen inches space was allotted for each with his bed and bedding; and deprived of the light of the day, as well as of fresh air; breathing nothing but a noisome atmosphere of the morbid steams exhaling from their own excrements and disordered bodies, devoured with vermine hatched in the filth that surrounded them, and destitute of every convenience necessary for people in that helpless condition." (*Roderick Random*, Chapter 25.)

Psychological Efficiency in the Heat

This important question may be approached in several ways. It may be discussed from the point of view of short exposures, that is, a matter of hours or at the most days, as contrasted with prolonged exposure as in the tropics. In either event the problem can be approached first of all from studies in the field, and secondly from the exact methods of an experimental laboratory. Field study is possible whereve men or women congregate for employment in atmospheres of unpleasant heat. Coal mines; gold mines; boiler-houses; engine-rooms; cotton mills; factories in the tropics; these are some of the pastures for the field worker. Of great significance is the performance of troops in tropical jungle or desert terrain, especially when the more skilled tasks are considered, such as marksmanship, signals, gun-laying, or tank manœuvring. Considerable experience has been gained by noting the performance of sailors in H.M. ships in the tropics, where most of the tasks are sedentary but highly skilled psychomotor activities (for example, range-takers, transmitting station operators, wireless telegraphists, high-frequency direction finders, or asdic and radar watchkeepers).

One must beware of certain intrinsic sources of error in these field-tests, especially when reliance has to be made upon subjective evaluations rather than objective scores. First, there is often an unawareness of the fact, not to mention the extent, of the falling-off in efficiency. Officers may hotly deny that they or their staff are any the less efficient during tropical campaigning, until actually presented with the proofs of their deterioration. This is due to the blinker-effect of high morale, traditional of the sort of man who never knows when he is beaten. On the other hand, the opposite phenomenon may occur, namely an hysterical exaggeration of any defects there may be, motivated by a desire to escape the discomforts, boredom, or dangers of a tropical milieu. This is a psychological mechanism apt to arise in the presence of an indifferent or inadequate morale. A third point is the question of how far it is possible to extricate oneself from the shackles of apathy, and to improve one's performance under the stimulus of volition or of strong emotion. It has often been argued that if action were joined all tropical langour would instantaneously disappear, and alertness, vigilance, and efficiency would return to a peak level. How far that belief is well founded is uncertain, and in any case there is an obvious danger in war of relaxing one's standards of performance and exhausting one's reserves for emergency use. Lastly, it is believed that there is a tendency for heat effects to resemble those described by Bartlett as occurring with fatigue, where there comes a tendency to be satisfied with one's own efforts but to blame others, or the machine, for any resulting defects. The subject becomes worried, irritable, and obsessed with his physical discomfort. "He is at once more optimistic about his performance and pessimistic about his state." (Bartlett, 1941.)

Bearing in mind these mental mechanisms, we may study the data. Among the earliest work was the industrial research of Wyatt (1926) on cotton operatives. In an environment of a high humidity, output reached its peak at 74° F. and fell off with higher temperatures. This was all the more striking because the higher wet-bulb readings increased the mechanical efficiency as shown by a reduced number of warp thread breakages. Similarly, Weston (1922) showed that the capacity of linen weavers dropped when the wet bulb exceeded 73° F. By increasing the air movement Wyatt was able to demonstrate a rise in human efficiency, while the fragility of the thread was not increased as this depended upon temperature and humidity. Steel and tinplate production, both carried out at very high temperatures, was shown by Vernon and others (1926) to fall off in the summer months. The same observers found that the rate of production of coal fell from a standard 100 per cent. at 73·5° F. dry bulb, 66·0° F. wet bulb, to only 59 per cent. at 86·2° F. dry bulb, 79·3° F. wet bulb. Sickness and accident rates were likewise much greater at the higher temperatures.

These foregoing studies date from the period 1922 to 1928. From then until the war a gap seems to have occurred.

In 1939 the Research Laboratory of the American Society of Heating and Ventilating Engineers made a study of the accuracy and variability of work carried out in hot spaces. They found that an effective temperature of 80° F. was consistent with maintained overall efficiency; but at an effective temperature of 87° F. there was a measurable decrease in the amount, accuracy, and variability of the work done. Unfortunately, levels between 80° F. and 87° F. were not studied. This interesting piece of research is also complicated by the fact that the researchers were at the same time studying the simultaneous factor of loud noise, though they were unable to note any deterioration in performance when the noise level was increased from 72 to 90 decibels.

Next, in order, come the American Naval Studies of 1943 (Pace and others, unpublished). Two groups of men were observed: both worked in hot environments, but whereas one set rested in the heat, the others rested in quarters cooled to just below the sweat-provoking level. A battery of thirty-two mental and physical tests was employed. In every case a better performance was noted in the men who rested in the cool. As might be expected, it was found that those in the cool slept better, and suffered far less from prickly heat, than did the others. The overall inefficiency may perhaps be ascribed to lack of sleep, fatigue, or the distraction of skin-irritation, rather than to the immediate thermal environment.

In Australia, Lee devoted much attention during the war to the difficulties of tank crews in desert warfare. He devised an ingenious gun-laying test which measured psychomotor efficiency. He was able to record the deterioration in performance, and also its improvement when air-cooled garments were worn—a device termed " personal air-conditioning."

During the war, the Royal Naval Personnel Research Committee also was gathering information from the field as to tropical efficiency. Observers in 1943 noted that in tropic-going ships, wireless telegraphists might become slow and inaccurate in transmitting signals, with a tendency to lengthen the dashes and to accentuate the dots. Wireless receivers would perhaps betray their inefficiency by their posture, their untidy penmanship, and a tendency to miss the first few words of a signal. Engine-room ratings were observed to be sleepy and lackadaisical in very hot weather, and when off watch they would turn in rather than read, write, or play cards. In submarines, before the introduction of coolers, personnel sometimes made silly mistakes. Two medical officers taking records in a hot and stuffy shell-handling room found difficulty in making correct arithmetical calculations. The ship's doctor found it an effort to embark upon the writing-up of his quarterly journal. On the gunnery side there may be a premature flattening-out or severe decline in the learning or working-up curve. All these data were of a psychomotor order and were independent of a falling-off in the performance of hard and heavy manual tasks. Men in key positions, requiring vigilance and rapid hand-eye co-ordination, became " drowsy and mentally sluggish." A high-ranking executive officer had previously made specific complaints on the score of slowness in the complicated human chain of operations between range-taking and gun-laying.

It is not easy to carry out a laboratory test upon the personnel in H.M. ships at sea prepared for action. Nevertheless, Ommaney-Davis (1944) devised an ingenious test for the speed of the visuomotor reaction-time and the accuracy of a manual performance. His results were suggestive but not altogether conclusive ; the endeavour is a notable one in being the first recorded instance of the employment of such a test in the field. It is to be hoped that other such investigations will follow.

One may now turn from field observations upon efficiency in hot environments to work of a laboratory order. Most of the available data comes from the Department of Psychology at the University of Cambridge, at the hands of Professor F. C. Bartlett, and his team of assistants, including the late Dr. Craik, Dr. Mackworth, Dr. Cameron, and others. Many of the investigations were carried out upon naval ratings, and not all the results have yet been published.

From these laboratories the first hot-room researches concerned the effect of a hot, humid environment upon a performance which combined heavy physical effort with accurate muscular control. An instrument called a persuitmeter was constructed for this purpose, and the task entailed the alignment of two moving pointers, one of which was heavily weighted. This work, equivalent to 210 kg./calories/hour, or 4 " met ", reproduces fairly well the naval tasks of gun-laying or the repair of heavy machinery. A series of trained and artificially acclimatized subjects was found to show impaired efficiency when an effective temperature of 85° F. was exceeded. It was noticeable that body-temperature began to rise before there was any detectable sign of deterioration in working efficiency.

The effects of heat and high humidity were next tested by Mackworth (1946) upon wireless telegraphists engaged in receiving morse signals. Mackworth found that a serious reduction in the accuracy of reception first appeared at an effective temperature of 87·5° F. An interesting correlation was noted between the telegraphist's technical competency, and his deterioration in the heat. The performance of competent wireless operators of ordinary ability was more severely affected than that of exceptionally skilled men. The " very good " operators occupied an intermediate position. Once again it was found that a rise in rectal temperature did not in itself lead to impaired efficiency in wireless telegraphy reception. The average number of errors per man per hour rose considerably and progressively throughout a three-hour watch period. As a rule, twice as many errors were made in the second hour, and three or four times as many in the third. Exceptionally skilled operators stood up to this ordeal better than those of average ability. There was no evidence that the deterioration was cumulative over a period of days.

A later report by Mackworth (1946) dealt with his " clock-test "—a visual performance test which mimics the work of a radar operator—which he had previously investigated under " normal " environmental conditions. The test involves close attention to the boring task of gazing for a long time at a visual display and noting the rare and quite irregular appearance of an unusual and inconspicuous visual stimulus. Long blank spells upon this synthetic radar apparatus led to the missing of about 25 per cent. of all visual stimuli, while during active spells only 2 to 5 per cent. of stimuli were missed. The task was now repeated in a hot, humid environment. It was found that as the temperature rose, so the human responses became sluggish ; a more marked change was a decline in accuracy. This falling-off in efficiency became statistically significant when an effective temperature of 87·5° F. was reached, the same figure as was noted in the case of wireless operators. An hour-to-hour decline in efficiency occurred, more marked in regard to accuracy than to speed of reaction. There was some evidence that previous look-out experience had an advantage in maintaining accuracy of work over a two-hour watch in a hot environment.

One may finally quote the study of a motor co-ordination test in a hot, humid environment made by Weiner and Hutchinson (1945). The subjects were instructed to pick up as quickly as possible with a pair of forceps a number of steel ball-bearings and to drop them through a series of holes along the periphery of a rotating disk. (This test is an elaboration of the one carried out at sea by Ommaney-Davis.) There were three groups of experimental subjects : (1) resting nude subjects

exposed for a short time to an effective temperature of 91° F.; (2) clothed subjects who had worked in an environment with an effective temperature of 88° F.; and (3) one nude subject who had lived for thirteen days in an atmosphere varying from 82° to 96° F. effective temperature. In all cases there was a deterioration in performance, as shown by slowness and clumsiness. This particular experiment did not demonstrate which level of temperature was the critical one.

Psychological Efficiency in the Cold

Here again one must distinguish between changes of a psychological character which may slowly develop as the result of prolonged residence in arctic or subarctic regions, and the alterations, if any, which may occur in efficiency through exposure to relatively short periods of uncomfortable cold. One must also distinguish between field observations and laboratory data.

As an instance of the problem of maintaining efficiency in the cold, Critchley's (1945) description of naval life in Arctic convoys may be quoted :

> " On the bridge or weather-deck, or in the control top of a ship in the Arctic, a watchkeeper may remain immobilized up to four hours, unable to keep warm by exercise. During this time he is required to keep alert at some responsible, if not vital task, the temperature being well below zero. Impeded by many layers of clothing, he faces a wind of high velocity with driving sleet or snow. Gradually, the bulky clothing proves tiring and burdensome. The high wind makes hearing difficult and handicaps intercommunication. Lacrimation and smarting of the eyes impair visual acuity. The northern twilight and the mist may combine with fatigue to produce visual illusions, so that the look-out may mistake a breaking top for a bow wave or the wake of a periscope. The pain of the intense cold produces a general sensation of distress, which, as it continues, more and more dominates consciousness. In this way attention becomes distracted ; the victim becomes slow and inaccurate in perception and performance. A mood of depression may supervene, though irritability is the commonest effect. Finger movements become clumsy, either through numbness from cold or because of the cumbersome Arctic handwear. Lastly, somnolence is common, and may become overwhelming when the rating comes off watch and goes below to his warm mess-deck.
>
> " The contrasting picture is that of a rating in the tropics, trying to maintain vigilance while crouched in some minute compartment with a dry bulb standing at 95° F. (I have known it to be 110° F.) and a wet bulb at 85° F. There may possibly be some near-by electrical apparatus which itself is generating heat to the figure of some 1 to 1·5 kilowatts, which is almost equivalent to the amount of heat that would be given off by 15 men at rest. He may be naked except for shorts; his body is streaming with sweat, and in addition he is probably covered with the irritating rash of prickly heat, perhaps secondarily infected. Hot nights—precluding regular sound sleep—diarrhœa, toe-rot, otitis externa, and other maladies and discomforts have perhaps already left their mark, and he has to cope with an exacting. boring, but highly important task."

How usual are the features common to these two pictures? How much is non-specific? and how much is due to the precise thermal component, that is, heat versus cold? To what extent do these two pictures resemble the reactions which take place as the result of a continuous and distracting pain stimulus? or as the result of an environment of intense noise? To what extent can both of them be related to a common factor of anoxæmia? These questions are crucial, but up to now they cannot be dogmatically answered.

Precise measurements of efficiency in the heat and in the cold can be sought first of all in the field, that is to say, in industry, in high-flying aircraft, in tanks, or in ships. Secondly, the study may be pursued under test conditions in a psychological laboratory, the temperature of which can be adjusted as desired.

The effects of relatively short exposures to cold have but rarely been the object of close psychometric study. We know that loss of manual dexterity will take place and interfere with the correct carrying out of psychomotor tests. Bedford (1937b) found that operatives engaged in assembling the links of bicycle chains took about 12 per cent. longer time to perform a standard task when the room temperature was reduced from 75° F. to 68° F. Hence we find clumsiness of finger manipulations, whether of machine-tools, predictor controls, gun-sights and aiming devices, or triggers. Hence, too, an enhanced accident rate in unheated factories. Such falling off in efficiency occurs, however, at a purely executive or effector level, and it does not follow that the central mechanisms are necessarily implicated. Nevertheless, there is some evidence that, in airmen at any rate, flying at great altitudes, there occur such phenomena as restlessness, distracted attention, mental distress, indifference if not distaste towards the object of the mission, and, later still, anxiety. Distorted judgment and intellectual falling-off, leading to incoherence, confusion, and torpor are also described (Armstrong, 1936 ; Grow, 1940). Some of these features, for example the restlessness and the wavering attention, may well be ascribable to simple non-specific stimuli of growing discomfort. The others probably lie outside that picture. More difficult to answer is the question how much these features owe to a mere oxygen lack, and hence whether they could be reproduced by a state of anoxæmia at a thermal-comfort level.

Such important matters, and many other related problems, can be answered satisfactorily only in an experimental cold room equipped with all the appurtenances of an experimental psychological laboratory. Undoubtedly there is a pressing need

for scientific data of this sort, and there seem to be few if any such facilities at any centre. In the United States there are, of course, experimental low-temperature chambers but they have been used mainly for testing the efficacy of protective cold-weather clothing.

Physiological Responses to Heat

This subject is one which has attracted considerable notice in the past seventy years. After Claude Bernard's monograph, *La Chaleur Animale*, written in 1876, there has been a series of able presentations and résumés. The work as it stood in 1926 and 1927 was brought up to date by two useful reviews, by Sundstrœm (1924, 1927) on the effects of tropical climate, and by Bazett also in 1927. The tropical side of the problem was later re-examined by Lee (1940). During the late war there was much physiological research carried out, stimulated by the operational needs for tropical campaigning. In Australia Lee and his colleagues were responsible for much study of the physiological problems entailed first by temporary sojourn within ill-ventilated air-raid shelters, and later (and in more detail) by the arduous duties of tank crews operating in a desert terrain. In America there was study of military (and to a lesser degree naval) problems in tropical warfare. Questions of acclimatization, physiological effects, optimum tropical clothing, and psychological efficiency were considered in great detail by Robinson and his staff (1943). The researches carried out by medical staff of the American Society of Heating and Ventilating Engineers deserve particular notice. In Great Britain naval requirements were responsible for the greatest advances, and hot-room studies were pursued by McArdle, Scott (1937-8), Weiner and Hutchinson (1945), and others. Unfortunately, most of this work has not yet been released for publication. It follows, therefore, that any such review as the present one will of necessity be already out of date, being largely unable to incorporate war-time studies. Of recent work which has not come under the ban of security may be mentioned the review by Blum (1945) on the physiology of sunlight.

Other countries contributed but little to war-time problems. There is, of course, the pre-war work of the Anglo-Iranian Oil Company's medical staff, as well as the valuable pre-war studies from the medical directorate of the Johannesburg gold-mining industry. Germany contributed little if anything.

The main facts dealing with the physiological adjustments can be readily studied in most text-books. The chief facts may be outlined here, as expressed particularly in the monographs of Bazett (1938) and of Lee (1940). The latter speaks of three stages in the process of human adjustments to heat, namely (1) immediate passive adaptation; (2) primary active adaptation; and (3) secondary active adaptation.

Immediate Passive Adaptation.—Elevation of the temperature of the skin-surfaces themselves, as well as of the lining membrane of the pulmonary alveoli, constitute a minor part in the physiology of heat-effects.

Primary Adaptative Reactions.—These include first of all cutaneous vasodilatation. This may be due either to direct action on the blood vessels of raised skin temperature; or local or central nervous reflex activities; or some humoral effect. Lee suggests that all three mechanisms may operate. The effects of this vaso-dilatation will comprise a rise of temperature of the part; transudation of fluid through the vessel walls into the tissues; increase in the insensible perspiration and in the amount of sweating; visceral vaso-constriction; and blood dilution. Vasodilatation probably also occurs in the respiratory tract, but it is suggested by Lee that this is of minor significance in man compared with animals, who lose heat by panting. The dilution of the blood previously mentioned is an early phenomenon, which is succeeded by the opposite process when there is fluid loss from sweating. (Lee dislikes and gives reasons for jettisoning the term "blood concentration.")

Sweating is, of course, the chief adaptative mechanism, in man at any rate. The rate of sweat-loss is very variable. Hot dry environments evoke a greater sweating than hot humid conditions, the effective temperature being the same. Mild degrees of dehydration depress the rate of sweating only a little. There is a considerable amount of individual variability in the number and distribution of the sweat glands; in the composition of the sweat; and in the facility or otherwise of the process of sweating. The interesting and valuable monograph of Kuno (1934) should be studied.

Secondary Adaptative Reactions.—These may appear after a delay if the circumstances are more severe. Lee mentions five of these reactions: rise of body temperature, increased pulmonary ventilation, decreased appetite, alteration of endocrine balance, and decreased activity.

Fever appears when heat gain outweighs heat loss. For obvious reasons it is technically difficult to assess the precise internal temperature of the body, and rectal readings are usually taken as sufficient. For more accurate work one may employ Murlin's formula, $T_b = \frac{1}{3}T_s + \frac{2}{3}T_r$. Where T_b = mean temperature of the whole body, T_r is rectal temperature and T_s the skin temperature. The physiological benefits of a rise in body temperature are not without their associated drawbacks, especially in respect to an increase in the metabolism, which may attain dangerous proportions. When equable and cool conditions follow, the body temperature usually settles to its normal level within a half to two hours; but occasionally a state of thermal instability may develop. The roles played by hydration and dehydration do not seem to be constant, though on

the whole thel atter state appears to exercise a deleterious effect in threatening thermal stability. The taking of food and physical work assist in raising body temperature.

Endocrine balance is altered by a possible reduction in thyroid activity, dubious alterations in the function of the suprarenals, a putative reduced activity of the islets of Langerhans, and an enhancement of the action of the posterior pituitary.

Increased pulmonary ventilation is especially seen in tachypnœic animals but only to a very minor extent in man. Lee says that " in man the reaction is archaic or adventitious, may easily become detrimental and is produced only under severe conditions."

Decreased alimentary function is shown by a relative anorexia, especially in unacclimatized persons first visiting the tropics, though there may be an initial day or two of hearty appetite.

Mental and muscular activity are both reduced in hot environments, whether climatic, industrial, or experimental. The change is best seen in the stage of non-acclimatization. Lee rightly distinguishes between various types of effort according to whether they are spontaneous or not. He recognizes three grades of effect: (1) light exercise undertaken spontaneously; here there is both reduced will to work and reduced activity; (2) most severe forms of work: fatigue rapidly follows; and (3) intermediate grades of work undertaken in response to demand: in such, neither the capacity of work nor the total energy production is necessarily altered.

Lee goes on to describe what he calls " adventitious involvements," stressing that it is difficult to demarcate between the physiological adaptative reactions, and phenomena which may be detrimental to the organism.

Cardiovascular disturbances must be included not only within the adaptative reactions but also among the adventitious involvements. If the blood volume/capacity ratio falls, there will result a reduced venous return, a reduced cardiac minute volume, a reduced blood pressure, and partial anoxæmia. Circulatory inefficiency produces disorders referable to many systems. Even the so-called " neurasthenia " and dyspepsia may be, according to Lee, the expression of protracted minor circulatory insufficiency.

Changes in the acid-base balance may be considerable and have been demonstrated by many workers, though much of the work is contradictory. According to Bazett, the tendency of altered circulatory rate is to render the blood more acid; but the direct temperature effect is in the opposite direction and actually outweighs the other, so as eventually to bring about an increased alkalinity. Nothing seems to be known, according to Bazett (1938), of any changes in the acid-base balance in the tissues.

Disturbances of the water and electrolyte balance may be expressed as dehydration (with its manifold attendant effects) and chloride depletion.

Disturbances of the nervous system constitute the fourth of Lee's " adventitious involvements." The clinical effects of such will be discussed later, but mention may be made at this point of the possibility that oxygen deficiency may be the *causa causans* of the nervous manifestations.

Physiological Responses to Cold

This subject was largely brought up to date in 1946 by Critchley in his William Withering Lectures. The subject may be divided chronologically into two periods, that is, up to 1939; and the recent war-time research.

Knowledge before 1939.—Omitting consideration of the local effects of cold, one may tabulate the situation as it existed at the outbreak of the war as follows.

1. We were aware that, within narrow limits, individuals differ in their tolerance towards cold: that healthy male adults of large build and moderate adiposity withstand cold best, though there are exceptions. Yet it is unlikely that anyone has summed up his ideas on the matter better than Moricheau Beaupré in 1826, who wrote, " Newly born, or sickly children,—lean and weakly persons,—individuals old or very impressible and irritable,—valetudinarians or exhausted debauchees,—convalescents,—those who have been tenderly reared and early accustomed to warm themselves,—those who habitually practice warm bathing, who perspire much, and do not regulate their clothing by the season,—the poor, who are ill clothed and nourished,—persons of morbidly changed sensibility, such as hypochondriac or hysterical persons, or those affected with organic lesion, as the phthisical, scrofulous, etc.; all those dread cold, and show themselves very sensible to it; children fear it less than adults, men than women; those of sanguine or bilious temperament are less chilly than those of the nervous or lymphatic. The fatty covering which clothes the extremities of the nerves, and retains the heat, shields from cold those who enjoy a succulent fulness of person."

2. That some measure of acclimatization is possible seemed obvious though its mechanisms were imperfectly understood.

3. We knew that there is a limit to the endurance of cold: that the operative factors include the environmental temperature; the velocity of the air movement; the conductivity of the surrounding medium; the duration of exposure; and the metabolic activity of the living organism concerned. It was known that, with ambient temperatures somewhat above freezing point, the heat-regulating mechanism of the body slowly drops behind; and that when the internal temperature falls to 20° or 22° C. serious if not fatal ill-effects result. At that time, however, we knew more about the temperatures and durations of exposure which prove lethal to insects, frogs, and rabbits.

4. The clinical effects of cold were a matter of common knowledge though little advance had been made over the preceding century. They may be said to comprise: a specific unpleasant feeling of coldness; shivering; reluctance to move; a tendency to adopt flexion attitudes; inattentiveness; irritability and depression;

rigidity and impaired motility; altered cutaneous sensibility; dysarthria; increasing discomfort, leading to pain, to be replaced later by an absence of bodily feeling; somnolence, torpor, coma, and death.*

5. Minor degrees of cold exposures had been studied superficially. An environment of mild cold was shown to be a circulatory stimulant, that is, until very low temperatures are attained. Basal metabolic rate is increased. Cardiac output is augmented, respiration is quickened. Blood volume decreases and leads to a certain amount of hæmoconcentration.

6. The cause of death from cold was uncertain. Though heart failure was most commonly blamed, some implicated a respiratory arrest; others anoxia; while others again visualized a direct cellular katabolism.

7. The morbid anatomy was regarded as comprising an early rigor mortis, with cutaneous patches of red discoloration. The cadaveric blood was said to be bright, the brain and viscera congested. Such changes were realized to be in no way specific for cold.

8. Certain mammals were known to be able to withstand long periods of severe cold by adjusting their metabolism. Hibernation, as this phenomenon was called, was not regarded as ordinarily possible in human beings.

Such, briefly, was the position of our ideas about the physiology of cold in 1939.

After 1939.—Early in the war a considerable amount of work started all over the world on the effects of cold upon man. The necessity of waging sea and land warfare in the Arctic, the Aleutians, and on the Russian front brought pressing practical considerations, and the fruits of these Canadian, American, and British researches have been rich. The main findings are tabulated below. The conclusions are given, rather than the arguments, and at times it will be necessary to quote the findings of anonymous workers whose researches have yet to be published.

1. Attempts were made to standardize some of the steps in thermo-regulation. The heat produced by an adult male while supine after a night of sleep and fasting averages 40 kg.-calories per square metre of body surface per hour. With the subject seated and at rest this output rises to 50 calories, and this figure has been suggested as a yard-stick or standard, to be referred to as the " met " (Gagge and others, 1941).

2. When the investing atmosphere is cooler than the body, thermal regulation automatically begins. With each fall of 1° C. in skin temperature, approximately 15 calories of stored heat are removed. Migration of blood takes place, and circulation is adjusted in such a way that the appendages are, as it were, sacrificed.

3. When cooling exceeds 1,200 calories the body tissues begin to freeze, and when the cooling rate is 2,000 calories the exposed face will freeze within one minute. When the ambient air drops to −50° F. or −60° F., mild exercise will cause frosting of the bronchi. In these ways we discern limits to human endurance. Operational and experimental data also afforded some clue as to survival rate. Nine sailors out of ten perished within thirty minutes of immersion in the Barents Sea, the temperature of which was 29° F. Of fourteen castaways on a raft near the Arctic Circle (air temperature below zero; sea temperature 32° F. (0° C.)) only six endured forty-eight hours' exposure, the first death occurring within half an hour (Critchley, 1943). Experimental work suggested that several hours' immersion in water at 68° F. (20° C.) would be very dangerous. With water at 50° to 59° F. (10 to 15° C.) the rectal temperature at the end of an hour was 92·3° F. (33·5° C.) and was still falling. Most unprotected men, it was thought, cannot survive immersion in water below 20° C. (68° F.) for " long " though no definition of this period was attempted. Vigorous swimming movements were not regarded as helpful, for heat production was probably already at a maximal level. Clothing makes very little difference to the survival rate.

4. Increased food intake is one of the means whereby body heat is maintained in the cold, and it has been computed that a man doing 4 mets of work will require 4,560 calories of useable food in a twenty-four-hour period, high carbohydrate and fat diets being better than a high protein intake. No virtue exists in a high vitamin ingestion.

5. Ever since the days of Vincent (1890) it has been traditional to associate the subjective feeling of coldness with the actual temperature of the skin. This assumption has been coupled with the belief that a skin temperature of an unclothed body between 88° F. and 92° F. (31·1° C. and 33·3° C.) is associated with a state of comfort. In the skin, end-organs for cold are believed to be more numerous than those for heat, and their threshold five times higher. But recently there has been an increasing tendency to relate the sensations of heat and cold to the rate of heat exchange rather than to the actual temperature of the tissues. Hence one can understand better the occurrence of cold feelings when the skin is warm, and warm feelings when the skin is cool; as well as some of the phenomena of acclimatization to cold.

* At this point may be quoted verbatim the description of the terminal events from exposure to cold made during the retreat of Napoleon's army from Moscow in 1812. The author, Moricheau-Beaupré, wrote as follows: " Shiverings, puckering, paleness, and coldness of the skin, livid spots, muscular flutterings and symptoms of the shock given to the vital forces; the person feels syncope approaching, his stiff muscles contract irregularly; his body bends and shrinks; his limbs are half-bent; sometimes lassitude and languor invite him to stop to repose; sometimes a feeling of weight and general numbness retard his steps; his knees bend; he squats down and falls; he then feels an invincible propensity to sleep; everything grows strange to him; his senses are confused; a thick veil darkens his view; his mind grows dull, his ideas incoherent; he stammers and raves; if he be free from suffering, he is not often so from agitation. Should you try to prevent him from stopping and sleeping, should you strongly represent to him the danger to which he exposes himself, he looks at you coldly and stupidly; if he has not lost all consciousness, he pronounces with difficulty a few words, entreating to be allowed to go to sleep; his relations with all surrounding objects quickly cease; he slumbers; the parts farthest from the centre of the circulation become cool; respiration, at first interrupted, becomes slow; the contractions of the heart become feeble, quick, hard, irregular, and sometimes painful; the pulse becomes smaller progressively; the central beat is extinguished; the brain is stupified; the pupil dilated; finally, a deep and mortal coma may be regarded as a certain sign of approaching inevitable death, unless the asphyxiated receive timely assistance."

6. A lot of work has been done on the scientific protection of the body against cold using the exact methods of clothing physiology. First came an attempt to measure the thermal insulating power of clothing. Gagge and others (1941) estimated the amount of clothing necessary to maintain in comfort a sitting-resting subject in a normally ventilated room (air movement 20 ft./min. or 10 cm./sec.) at a temperature of 70° F. (21° C.) and a humidity of less than 50 per cent. This unit of insulation they called the clo. One clo is roughly equivalent to one's indoor clothing—or a top-coat alone. The clo unit has not escaped criticism, especially by textile research workers in this country. Pierce and Rees (1944) of the Shirley Cotton Research Institute have suggested as an alternative a unit of thermal resistance which they term the "tog". By definition, a tog is the resistance which will maintain a temperature difference of 0·1° C. with a flux of 1 watt per square metre. This is the resistance of a light summer suit, and 10 togs represent about the thickest clothing that can be carried. The same authors have also proposed a standard measurement of the physical efficiency of clothing based on the ratio of the equivalent air thickness of clothing to the weight per unit area. This quantity is given as the "thermally effective specific volume" (T.E.S.V.) and its ratio to the actual specific volume, which may be called the specific thermal resistivity, is a useful measure of the efficiency of the structure of the material.

7. Much thought has been given to the scientific clothing of troops for Arctic warfare. The intermediate steps need not be narrated, but the end-result can be witnessed in such items as the Brynje system of dress; the naval Anaraks; the scientific juxtaposition of pile suitings with wind-impermeable outer layers; improved foot- and hand-wear; the scientific design of garments so as to trap insulating layers of air, to seal leakages at the neck and wrists, and to strike a correct balance between undue warming of the extremities as opposed to the trunk. Electrically-heated suits have been devised, improved, and adopted, especially for air crews. Lastly, attempts have been made to construct "exposure suits" to protect shipwrecked seamen in waterlogged dinghies or rafts, or pilots ditched in northern waters.

8. Some work has been done on long-continued exposure to cold. Wartime researches found that there occurs a fall in rectal temperature as well as in basal metabolic rate (−10 to −15 per cent.). These observations suggest that in certain circumstances, and with a restricted physical activity, something like modified hibernation can occur in man.

9. Acclimatization, or habituation, to cold is known to be possible, and some of its mechanisms are recognized. Although from a physiological angle it is in many ways the opposite process to tropical acclimatization, nevertheless practical experience shows that at times unusual hardiness to extremes of both heat and cold can exist at the same time in the same person.

10. Neurological and psychological reactions to cold have as yet been studied only superficially. As regards the peripheral nervous system, we know that fibres of different thickness have a differing vulnerability towards freezing. The electrical activity of the cortex, posterior hypothalamus, and medulla are also depressed in the cold. On the other hand the sympathetic and the parasympathetic systems are apparently stimulated in cold states. Psychomotor efficiency in the cold has been touched upon by work carried out in the Armoured Vehicles Medical Research Laboratory, Fort Knox. An environment of −20° F. markedly inhibited the performance of the Johnson Code Test—a paper and pencil test. But since the percentage of errors did not rise, the falling-off was ascribed to loss of digital dexterity rather than to cortical depression. Measurement of response to visual stimuli showed no deterioration in reaction-time or in precision. On the contrary, another set of investigations showed that cold baths produced a striking if temporary improvement in visual acuity, binocular vision, critical fusion frequency, tapping rate, and eye-leg muscle-reaction time. Hand strength, as measured by grip pressure, decreased about 28 per cent. after three hours' exposure to cold (−10° F. to 15° F.).

11. Changes in gastric secretion and peristalsis in cold environments have been described by Roth and Gabrielson (1940). These findings may prove to have clinical repercussions in the incidence of peptic ulceration after exposure.

During the war years German physiologists were also interesting themselves in the practical problems they encountered, not only in their winter offensive on the eastern front, but also among pilots ditched in the cold seas off the British Isles.

Often it had been found that after rescue, and while in an atmosphere of warmth and comfort, the patient might collapse and die. It was to obtain a better knowledge of this so-called *Rettungskollaps* (resuscitation collapse) or *Weidererwärmstod* (re-warming death) that Weltz and his associates (1942) tried to reproduce this phenomenon in animals by chilling them to the point of death and then dipping them into water at 45–60° C. (113°–140° F.). To their surprise their animals revived and survived. It seemed as though they had stumbled upon some obscure aspect of cold-physiology which promised to have important theoretical and practical bearings. Research projects were drawn up, and one of the first tasks set was to determine the mechanism and exact nature of death from cold. The problem was far from simple, and agreement was never reached. While a few ascribed death to molecular changes ("*Gewebschädigung*") more and more suspected an oxygen lack to be the responsible process (Werz and others, 1943). Of course, anoxia does not necessarily preclude the simultaneous intervention of a cardiac failure due to a direct though reversible action on the heart muscle. They found that the *Spättod*, or delayed death after resuscitation, could at times be prevented by artificial respiration or by the use of oxygen under pressure.

These interesting physiological studies had a bearing upon the practical handling of ditched airmen and shipwrecked sailors. They began to try rapid rewarming methods by putting the rescued in a bath of water at 45° C. (113° F.). New directives were promulgated. Castaways were advised to dress as warmly as possible and to remain quiet and immobile in the water or in their raft rather than to engage in physical exertion. It was asserted that after abandoning ship, stokers endured the cold better than seamen, even though they were less well protected by clothing: this paradox was ascribed to a process of "pre-heating" which had taken place while in the engine or boiler room. Other medical studies of survivors are exemplified in the electro-encephalographic researches of Noell. He found no anoxic patterns in the brain-waves, and he regarded the records as reminiscent of eserine poisoning. At still lower temperatures the tracings resembled the effects of strychnine. Noell drew many tentative theoretical conclusions of a physiological nature, the upshot of which tended to discredit the anoxia hypothesis of cold.

Acclimatization

It is, of course, a commonplace that toleration of a hot environment increases with habituation, but it is only of recent years that attempts have been made to study the nature of this so-called "acclimatization." It is a process witnessed not only among newcomers to the tropics, but also in those who enter industries where work is carried out at high temperatures. Acclimatization is possible not only to atmospheres of high temperature but also of high humidity; but it is open to argument how much these forms of acclimatization are specific. That is to say, habituation to a desert climate may or may not lead to increased work-capacity and comfort in a jungle climate. The phenomenon of acclimatization is complex and entails other factors besides the purely physiological ones, which alone have been the subject of exact study. Certain psychological factors enter the process, and certain attitudes of mind and certain degrees of mental and bodily activity lead to a more rapid adjustment to high temperature environments than others. Modifications in working-hours, in diet, in resting spells, and in social custom may be necessary before acclimatization can be said to be perfect. Perhaps for such reasons certain nationalities or races, for example, Spaniards and Jews, are sometimes regarded as the most suitable type of tropical inhabitant, though not necessarily the best colonizers.

We know that acclimatization is a process which takes time to perfect itself, and that it can be induced spontaneously or artificially. In the latter case it can be effected slowly or more rapidly according to differing techniques. Furthermore, we know that acclimatization is not a permanent state, but is one that can be weakened, modified, or lost altogether. We believe that some exceptional individuals never succeed in attaining complete acclimatization. These aspects of what might be called the pathology of acclimatization are only dimly envisaged and are far from comprehended.

Up to a decade or so ago acclimatization often developed spontaneously, as it were, by a gradual mounting of the temperature experienced during the sea passage from the United Kingdom to the East. Today, however, a person may be in the cold and damp of London one day and in the arid heat of the Persian Gulf or the humid atmosphere of Bombay thirty-six or forty-eight hours later; and the subject who embarks upon this air trip may be elderly, debilitated, or feeble. This last point raises the issue of whether there are any anthropometric features which influence the rate and efficiency of acclimatization. It is a common experience that a high degree of physical fitness, or an athletic habitus, do not necessarily mean that an individual can adjust himself well to tropic heat, and that the undernourished may actually endure that heat better than the average. Such paradoxical instances are probably the exception, but they are, nevertheless, striking. It is for future study to determine with precision which qualities of body build, stature, colouring, and hirsutism are important in this connexion.

The physiology of acclimatization, as far as we imagine it, entails first a greater degree of circulatory and muscular efficiency, so that physical work is carried out with less rise in skin and rectal temperature and a more stable blood pressure. There is, secondly, a change in the secretion of sweat, though the nature of the change is not at all constant. The rate of sweating may become greater or less, and the composition of the sweat (and in particular its salt content) may alter. Perhaps it is not inaccurate to sum up by saying that the resultant of these changes is to bring about greater evaporative cooling, and a conservation of body-chlorides.

The instability of this acclimatization to heat is well shown in industry. In the Rand gold mines it was found that after a few days' absence from work the heat tolerance of a miner was very upset, so that he needed to return first to a probation gang before resuming his proper job. An intercurrent illness, and even a week-end carousal, similarly upset this acclimatization more or less profoundly.

These facts may perhaps have a bearing upon the propriety or otherwise of introducing "artificial" climates or environments in the tropics. The risk, albeit a faint one, of disturbing natural acclimatization, by working, or alternatively by sleeping, in air-conditioned environments must be studied. The optimum difference in temperature and humidity between the ambient air and the air-conditioned compartment needs to be established.

The question of artificial and rapid acclimatization of workmen or troops for tropical service, has arisen for a great many years. Early in the last war it was rumoured that the Germans were training their tank crews for the Afrika Korps in hot chambers in Europe. As a matter of fact this was not the case, but they were relying on the old custom of training these soldiers in intermediate climates. The naval surgeon, Armstrong, in 1843 noticed that sailors joining the West Indian fleet benefited by a short stay en route in Bermuda or at Gibraltar. So the Germans used Sicily and the south of Italy for working up the Afrika Korps.

Before the war native recruits to the Rand gold mines were put through a preliminary acclimatizing course. Within a hutment artificially heated to an effective temperature of 93° F., they were made to shovel stones for an hour or so. Oral temperatures were taken every fifteen minutes. Those who developed a fever of 103° F. or over, and those who collapsed, were rejected out of hand. Doubtful ones were put on a probationary period of light work for four or fourteen days before being sent to work in the hotter or deeper parts of the mine. This procedure—originally devised as a means of acclimatization—became more and more used as a selection technique.

Work carried out in the United States during the war by Robinson and others (1943) showed that a satisfactory degree of acclimatization could be produced artificially and in a short time. In a laboratory hot chamber simulating desert conditions (T. 104° F.; humidity 23 per cent.) men walked on a treadmill for one to one and a half hours a day. At first this effort produced heat exhaustion, but tolerance increased rapidly during seven days and thence more slowly up to twenty-three days. Heart rates declined from an average of 178 at the beginning to 155 on the seventh day. The average skin temperature fell from 98·4° to 96·5°, and the rectal temperatures from 103·4° to 101·7° F. The degree of acclimatization attained on the seventh day was 80 per cent. of the improvement reached on the twenty-third day.

It is probable that the rate and adequacy of acclimatization to the tropics is bound up with certain physical and constitutional characteristics. Just as certain types endure tropical conditions better, so they may respond better to artificial acclimatization. Individuals who are in good physical condition acclimatize better than those who are "soft," "flabby," or debilitated. The relation of surface area to body mass, the colour of the skin, the previous habit of muscular exercise, and the state of the blood vessels and heart are probably significant.

Habituation to cold environments is a process which has been studied less thoroughly. The term "acclimatization" is not as a rule applied to this phenomenon. "Hardening" or "conditioning" or "seasoning" have been in use at various times, and, many years ago, the expression "indigenization." This process is slower than acclimatization to tropical conditions. Physiologically speaking, there is a habit of cutaneous vasoconstriction directed towards a reduction of the heat-loss from the skin. Central blood vessels dilate; blood volume is reduced; and there may be a relative hæmoconcentration. The blood pressure fluctuates until reaching eventual stability, starting with an early though transitory rise. Muscular activity is enhanced, and with it appetite is stimulated and calorific intake augmented.

It is traditional, when discussing habituation to the cold, to refer to the Indians of Terra del Fuego, who wear few if any garments although the temperature of the ambient air is below freezing point. In such conditions it is debatable whether their actual skin temperatures are maintained at a relatively high comfort level by a highly efficient vasomotor mechanism, or, on the other hand, whether their threshold for cold-discomfort is altered by habit.

Toleration towards the cold, like acclimatization to the heat, is a mechanism, which may be lost or weakened as the result of various circumstances. Debility following intercurrent illness certainly reduces powers of enduring cold, especially if it is accompanied by loss in weight. It has been suggested that simple prolonged exposure to cold may lead in time to a lessened habituation, as, for example, in polar explorers. There is a possible fallacy here, in that vitamin deficiency and, in particular, a state of scurvy may be the more direct cause of weakened resistance.

The question has been touched upon elsewhere whether acclimatization to the heat and hardening to the cold are complementary or antagonistic processes: whether endurance to the climate of the tropics is reduced by prolonged residence in a cold country, or *vice versa*. In so far as the physiological adjustments in blood volume are concerned, the two forms of acclimatization may be looked upon as different. Certainly, in persons in mediocre health or with poor stamina previous residence in one sort of climate is a disadvantage if they change abruptly to the opposite type of climate. It is probably otherwise with individuals who are in "hard" condition, or in a state of high muscular

and cardiovascular efficiency. Certainly it is a fairly common experience that a homecomer from the tropics may endure the cold and wet winter of this country surprisingly well, for one season at any rate. Again, it is known by explorers and by campaigners that an individual might prove relatively immune both to the rigours of cold weather and to the heat of the tropics. Cherry-Garrard informs us that, of the members of Scott's Antarctic expedition, the man who was least affected by the cold was an officer of the Royal Indian Navy who had come directly out from the Persian Gulf and who was notoriously indifferent to extremes of both heat and cold.

Nowadays we are increasingly faced with possible ill-effects of abrupt changes from one climate to another, as in air travel. This is especially important when elderly or debilitated statesmen or officials are flown from the wintry United Kingdom to the desert climate of Asia Minor or the jungle environment of Ceylon or Singapore in the course of a couple of days. It is well known that a change from one sort of climate to another is stimulating and beneficial. Herein lies the benefit of change of air. Herein too is the drawback of an equable climate without seasonal change. But when the rise, or fall, in temperature is excessive, or occurs too abruptly, there may be untoward consequences, especially if the individual concerned is elderly, hyperpietic, or arteriosclerotic, or if he is engaged in arduous mental or physical work.

General Effects of Prolonged Exposure to Heat

In those who have come to live within the tropics, there may develop after a few weeks or months certain changes which belong to the borderland between physiology and pathology. There may arise changes in various vegetative functions which, without in any way constituting a disability or a malaise, have to be taken into account when estimating the clinical norm for tropical residents. Alterations in the rate and volume of sweating and in the composition of the sweat have already been mentioned, and these belong to the process of acclimatization. But a general steady reduction in weight perhaps lies outside that process of acclimatization, and doubts may be engendered as to whether this thinning is a natural or a morbid manifestation, and how far it should be investigated and, if possible, checked. There is the same problem in assessing the " normal " temperature of tropical residents. This point is important (and often overlooked) in much of the physiological work on heat-load and acclimatization. It is important, too, in preventive medicine in the tropics and in the vigilant watch for the early stages of disease. Renbourn and Bonsall (1946) have brought this question up to date. Sundstrœm (1927), Radsma (1938), and Mason (1940) noted that the mean temperature of tropical white residents was above the usual normal. Castellani (1938) denied that the tropics altered the temperature level. From the work of Renbourn and Bonsall it was found that during the summer months in North India the oral and rectal temperatures of military personnel, Indian and British, showed levels above those accepted as normal for temperate climates. Oral temperatures up to 100·6° F., and rectal temperatures up to 101° F., may occur in apparently normal subjects. The distribution curve of 894 cases was not significantly skewed. Other interesting points emerged from their research. It was found that an individual tended to have his own characteristic daily temperature curve, and that on a particular day a group of individuals would behave in the same way as regards oral and rectal temperatures. It was not always possible to find a significant correlation coefficient between resting oral and rectal temperatures. Some subjects—albeit few—had mouth temperatures which lay at a higher level than the rectal readings. Analysis of groups of men and of several individuals, British and Indian, suggested a seasonal trend in the mean oral temperature which depended upon the ambient temperatures. Exercise in the rain might cause a fall in the mouth temperatures. Oral records are probably not a satisfactory indication of the internal temperature of the body.

Other minor deviations in physiological norms and functional activities may be traced in alterations in amount and nature of food ingested; changed water metabolism; broken nocturnal sleep; disturbed habit of alimentary evacuation. We know relatively little of such matters; at all events the precise physiology is obscure. (Hair growth, menstrual history, fertility, and sexual potency have also to be studied.)

The minor psychological changes which accompany tropical residence are a commonplace and of special interest. They will be discussed later.

Sickness Rates in the Tropics

It is sometimes believed, if not assumed, that intercurrent maladies last longer in the tropics and require a longer period of convalescence. The same belief applies to the effect of wounds and injuries. This important matter can be studied only by dealing with much clinical material. One might compare the man-days lost from various types of intercurrent sickness in, say, two regiments, one stationed in the tropics and one in the United Kingdom. Better still, for a ship's company is much more of a closed community, one might compare two ships of similar class and size, one

in home waters and one in, say, the East Indies Fleet. Or one might compare the office staff in a business house in India, Iraq, or Iran with the headquarters staff in London. The various errors which may creep in to invalidate such data must not be forgotten. A ship might put in at an Eastern port, and an outbreak of gonorrhœa result and throw out the total sickness rate. In home waters the higher incidence of upper respiratory infections might complicate the comparison. Some of these fallacies might be avoided by setting out the sickness returns under various nosological headings or system-diseases. Although this enormously increases the burden of the recording medical officers, it pays dividends in producing statistics which can be interpreted. Fraser-Roberts, the Admiralty consultant in medical statistics, in the latter days of the war prepared an analysis along these lines. Divested of the various associated points of interest and of difficulty, the figures revealed that the average number of man-hours lost through sickness is about double in the tropical ship compared with one in a temperate climate. It is, moreover, of great interest to find that the man-hours lost through accidental injury were also twice as great in the tropical station—an observation which affords much food for thought.

Tropical Disease Proper

There is no need to dilate upon the occurrence of the parasitic and other diseases which are characteristic of, or peculiar to, tropical regions, or to discuss at length the part played by such disorders in industrial hygiene or absenteeism. The point need only be made that many, perhaps most, of these affections are preventable, in theory at any rate; and it is not too much to hope or foretell that the future might see such affections stamped out. The 1939–45 war brought to many tropical scenes American lavishness in screening of huts and dwellings; repeated routine examination of the stools of native employees, with elimination of all dysentery carriers; liberal use of new repellents and insecticides—if necessary applied from the air; uprooting and destruction of suspected native quarters if located too near European settlements; free use of refrigerators. Such reckless but logical even if drastic steps in preventive medicine taught us a lesson in hygiene.

Morbid Effects of Heat

From the discussion upon the physiological effects of hot environments, it is obvious that adaptative reactions tail off gradually into adventitious involvements, to use Lee's terminology, and that the mechanism of thermoregulation is a delicate one easily deranged by excessively severe external conditions, or by a series of internal unfavourable circumstances. Thus, extremes of age, malnutrition, hunger, dehydration, corpulency, fatigue, alcoholic habit, intercurrent illness, or trauma, may combine to throw out of gear the workings of the body's adjustment to undue heat. Even before such a stage, however, and while the body can be said to show satisfactory adaptation to the heat, psychological or psychomotor inefficiency may be demonstrable: in this way a morbid effect can already be traced.

If tropical residence is added to the industrial and experimental environments of heat, then the possible morbid effects can be given under four headings: (1) specific heat effects; (2) enhancement of man-hour wastage from intercurrent illness; (3) tropical disease proper; and (4) the psychological effects of protracted existence in the tropics. The specific heat-effects form an interesting if complex chapter in medicine, and for details one can refer to the numerous excellent studies that are available. Three main disorders are recognized, namely (1) heat exhaustion (heat syncope, heat prostration); (2) heat stroke (hyperpyrexia); and (3) heat cramps. In addition, we must consider the possible specific ill-effects of sunlight.

Ladell and others (1944) have modified somewhat the traditional conception of heat exhaustion by two clinical types. Their type 1 was characterized by conspicuous degree of dehydration and was regarded by them as a salt-and-water deficiency in individuals who have sweated excessively and who are by nature prone to excrete large amounts of chloride in their sweat. Cases which they relegate to their type 2 began to occur towards the end of the Iraqi summer, and a breakdown in the sweating mechanism was envisaged. Three possible causes were proferred for this: (1) glandular fatigue following prolonged overactivity; (2) central or peripheral failure of the controlling mechanisms; and (3) pathological changes in the glands themselves. The authors could not determine with confidence which mechanisms were responsible, but they were impressed by the presence of cutaneous changes due to protracted prickly heat.

The heat exhaustion type 2 of Ladell and others resembles in some ways the "thermal dysidrosis" described in American soldiers in the Arizona desert by Wolkin and others (1944). The authors' table of comparison between type 1 and 2 of heat exhaustion is reproduced in Table 2.

Heat stroke or hyperpyrexia is in the tropics a well-known phenomenon which has been abundantly documented and studied. Modern preventive methods put in force after the first year or two of the war probably went a long way towards reducing the incidence. The difference between the case-numbers in Mesopotamia in the first and second world wars is striking. Ladell and others (*loc. cit.*) had experience of only twelve cases, but their biochemical findings supported the idea that hyperpyrexia is accompanied by a superhydration. Heat stroke occurs when thermoregulatory mechanisms fail to compete with the environmental temperature and an abrupt cessation of sweating is the threatening

TABLE 2

COMPARISON OF CLINICAL FINDINGS IN HEAT EXHAUSTION, TYPES 1 AND 2

	Type 1	Type 2
Number in group	45	55
History		
Vomiting	73%	4%
Cramps	70%	4%
Defective sweating	13%	87%
Increased frequency of micturition *	0	82%
On admission		
Dryness of skin	5%	40%
Desquamating prickly heat	7%	80%
Signs of dehydration	50%	2%
Pulse volume poor	33%	0
Lying pulse-pressure less than 30 mm. Hg	46%	2%
Blood-pressure not maintained on standing	72%	2%
Colour of skin	Pale	Red
Av. lying pulse-rate (beats/min.)	90	76
Av. incr. of pulse-rate on standing (beats/min.)	40	20
Av. lying blood-pressure (mm. Hg)	111/79	121/69
Av. rectal temperature (°F.)	100·6	100·9
Av. mouth temperature (°F.)	98·2	99·5
Av. frequency of micturition (per 24 hr.)	2–3	9
Av. weight gain in hospital (oz.)	121	41

* By "increased frequency of micturition" is meant passage of urine five times or more in twenty-four hours.

symptom of acute symptoms over a period of half an hour to three days. Frequency of micturition during this phase is a significant feature.

According to Brunt (1945), for nude men resting indoors the limiting environment in a hot dry climate is 113° F. for a relative humidity which is nil, or 106° F. for a 20 per cent. relative humidity, when the air movement is 17 feet per minute. In a hot wet climate, with the same rate of air movement, and a relative humidity of 100 per cent., 88° F. is regarded as the upper limit, above which heat stroke occurs; or 93° F. when the relative humidity is 80 per cent. The author has been taken to task for these figures, which some would regard as too low.

It is probable that both heat stroke and syncope from heat exhaustion were responsible for most of the deaths in the Black Hole of Calcutta incident. The mortality rate is high in cases of heat stroke (hyperpyrexia), and there is some evidence that European survivors are rendered permanently unfit for further tropical service, from an acquired sensitivity to the heat.

Heat cramps constitute the third well-known effect of raised temperature. The latest review of the subject, by Sneddon, deals with its occurrence in units of the British Pacific Fleet during the war 1939-45.

Psychological Effects of Tropical Residence

Although these are denied by many tropical residents, it is nevertheless a common experience that persons visiting the tropics for the first time may note certain prominent traits or features in the residents: undue irritability, sometimes directed particularly against the indigenes; alcoholic habits which surprise the newcomer; mild hypochondriacal preoccupation; feelings of frustration, or resentment, which have a very paranoid flavour. The combination of mild bodily malaise with general mental and physical lassitude was recognized by Castellani and dubbed "cacophoria tropicalis."

Such changes were very commonly encountered during the war 1939–45 among personnel of the fighting Services. In the Services stationed within the tropics, such personality-trends were a topic of common discussion, often in a facetious vein. It was commonly believed, or at any rate proclaimed, that after a year there would develop a deterioration in drive, alertness, keenness, memory, capacity and speed of thought, and the power of making decisions. Accompanying these features there might be a certain slackness, procrastination, irritability, and sometimes bibulousness. Ratings and other ranks might drift into a slovenliness in dress and appearance quite foreign to their practice in European stations. This, coupled with uninhibited conduct in public with incorrect, unrestrained, and often violent conduct toward the natives, might become a matter of concern to the authorities. Such phenomena might be both subjective and objective; that is, the victim might be aware of his changed personality, just as it might be conspicuous to others.

There can scarcely be any reasonable doubt that very real changes occur in personality, mood, and conduct. Whether these are accompanied by any actual and measurable falling-off in efficiency is less clear, though it is very likely. The problem differs according to the circumstances. That is, the causation of these psychological changes may be very different in war service personnel sent to a foreign station against their inclinations, from what it is in the tropical resident who has deliberately embarked upon his career in that particular climate. In the former case, any change in personality is more likely to belong to the category of the neurosis, with hysterical features motivated by a strong, though perhaps veiled, desire to return home; a nostalgic reaction in fact. In the case of the tropical business man or civil servant, the psychopathology may be quite different.

Climate is not, of course, the sole environmental factor responsible for psychological changes. The association with indigenous subordinates, with their own often inscrutable ways; chronic ill-health; a sense of frustration and exasperation with authorities and the organization at home; flies; defective sleep; isolation; boredom; unnatural social life; these may all play a part. In the armed forces there are additional factors such as family domestic anxieties and perhaps financial ones; lack of amenities; uncomfortable quarters; unfamiliar diet; the strain of enemy action in wartime.

The literature has much to say on the question of so-called "tropical neurasthenia," but it must be admitted that the subject has not been considered adequately. Originally this form of neurosis was thought to be very common and to be due mainly to the ill-effects of climate. Later there came a tendency to decry the status of this affection; to regard it as relatively rare; and to ascribe its existence, where it did occur, not so much to climate as to sociological factors. During the war 1939–45 the pendulum swung back, and service personnel begun to regard neurotic symptoms as the expected concomitants of tropical residence, and to attribute them to the effects of heat, whether dry or humid.

The time is ripe, therefore, for a more scientific evaluation of this subject. Its relationship to climatic factors would be strengthened if it were possible to demonstrate certain phenomena: (1) if tropical civilians were liable to the same symptoms as naval and military personnel stationed in the Far East, this would implicate the factor of climate as opposed to homesickness; (2) this would also be so if psychological symptoms were found to be cured by leave periods up country, or prevented by regular spells of that sort; (3) if certain clinical differences were to be found between tropical neurotics and neurotics in the home country, it might be argued that the heat had something to do with the determination of the particular symptoms; (4) if there were found to be a parallelism between fluctuations in the weather and the clinical waxing and waning of psychiatric symptoms, the inference would be suggestive; and (5) if it were capable of proof that those born in the tropics improved in mental efficiency when they emigrated to a cool climate, the ill-effects of environmental heat would be still further suspected.

These points are worth examining.

1. Despite the occasional and perhaps over-emphasized disclaimers, it is hard to escape the conclusion that neuroses are commoner in the tropics than at home, in European and North American settlers at any rate. It is granted that civilians are probably less affected in this way than members of the armed forces. Few would deny that in time, that is, after a year or two, a state of apathy, or inertion, or perhaps actual inefficiency develops, associated with anhedonia or mental malaise. That such manifestations are temporarily improved by a sojourn in a more temperate hill station seems indubitable; better still by a period of leave at home. The common practice of firms and government offices insisting that their employees take long and frequent periods of leave is eloquent testimony here.

We may turn, in this connexion, to the invaliding statistics from tropical stations, based upon European personnel who originally passed a rigorous physical test, and who elected to leave the home country to make their career in isolated and unsalubrious regions of the tropics. Here the Colonial Office figures are suggestive. Psychiatric disorder was responsible for 1 out of every 3 invalidings from East Africa and 1 out of every 2·7 from West Africa. Alcoholism was responsible for 1 out of every 24 and 30 respectively. (Tropical disease proper, for example, malaria, dysentery, etc., accounted for 1 out of 9 and 1 out of 10 respectively.) One in 6 and 1 in 3·8 deaths were directly due to tropical diseases in East and West Africa respectively, while 1 in 11 and 1 in 13 were suicides. Some early figures are available for the United States Army. Of 166 psychotic soldiers recorded in 1901, 120 were stationed in the Philippines. In 1902 the figures were 114 out of 186. In 1903 the suicide rate was 7 per 100,000 in the U.S.A. and 16 per 100,000 in the Philippines for Army personnel. Out of 189 cases of sickness in the Dutch East Indies in 1920, for which leave was granted, 111 were instances of psychological disorder.

2. It would be interesting to study records of the incidence of neurosis in tropical employees before and after the installation of air-conditioning plant in the homes, offices, and factories. Unfortunately, no such figures appear to be available as yet.

3. Comparison of the clinical features of the neurotics in temperate climates and in the tropics is important, and seems to show some minor differences. Anxiety and depression, in various degrees of association, are the characteristics of commonplace psychogenic disorders at home; next in frequency and importance come psychosomatic affections, with their predominant cardiac, gastric, colonic, or aphalic reference. In the tropics, however, the picture seems rather different. Intense irritability, poor memory, and mental and physical lassitude are more conspicuous. How far these clinical differences depend upon the factor of climate is, of course, another matter.

It might be helpful to compare the clinical features of the psychotic illnesses in the tropics with those occurring at home. As regards service personnel, short-lived schizophrenic episodes seemed conspicuous, independent of geography and of climate. The bizarre psychoses that have been described under the terms *latah*, *amok*, *koro*, *uas-uas*, are quite outside psychiatric experience at home, but racial factors are more likely to be significant than climatic.

4. More directly related to weather influences are the well-known mood changes associated in the tropics with dry winds and high velocity. Such meteorological phenomena may induce symptoms of their own, or may

exaggerate any pre-existing neurotic or psychotic features. The *mistral* of the South of France leads, as is well known, to the curious irritability known as *le cafard*. The *Kkamsin* of the Levant, the *harmattan* of West Africa, and the *Xirocco* of Malta are all notorious climatic phenomena closely bound up with psychiatric effects. To these may be added the *solano*, the *pamperos*, the *ghibli*, the *fœhn*, and the *samum*. We may even quote Dexter's observation that Denver school-children were more unruly when strong southerly winds were blowing.

5. Though the problem is difficult to establish scientifically, there is an impression that when Indians, Chinese, negroes, and other tropical indigenes leave their homes and emigrate to cooler parts, their capacity for efficient mental work improves. The only scientific observations of this kind were made by MacKinnon upon European children born in Kenya. At first they seem to develop intellectually at a superior rate to those at home, but after the age of 10 or so a gradual mental tiredness and deterioration seemed to set in.

Morbid Effects of Cold

Considerably less is known on this subject, and it seems probable that on the whole the frigid regions of the globe are healthier as dwelling-places for man than are the tropics.

Specific Cold Effects.—These need only be mentioned. They include such conditions as chilblains and frostbite (and the related disorders of immersion foot and trench foot). There is the question of the deleterious effect of cold environments upon pre-existing cardiac, cardiovascular, and cerebrovascular affections. Perhaps (as will be discussed later) the responsible trauma is not so much the question of cold, as an abrupt transition from one temperature to another, or one kind of climate to another.

The question of how far cold climate or cold exposures can precipitate the symptoms of other types of disease is unsettled. The tendency to relate acute respiratory infections (upper or lower) to sudden exposure, is less prominent now than formerly. Even rheumatic and pararheumatic disorders are less often ascribed to low temperatures nowadays. The experience of shipwrecked personnel during the last war showed clearly that men may endure astonishing degrees of cold exposure without developing such sequelæ as pneumonia, nephritis, fibrositis, or even simple head colds. The beliefs of the last century that certain organic spinal diseases were somehow related to cold exposure—myelitis, tabes, sclerosis—is now almost entirely discredited. What has been said earlier regarding the cause of death from cold suggests that the ill-effects can be narrowed in all probability to those of cardiac or circulatory origin.

Arctic and Antarctic Diseases.—Specific arctic and antarctic diseases cannot be identified in the way that tropical affections can, largely because of the comparative rarity of insect and bacterial life and other potential parasites. The mosquitoes so common in the subarctic summer are probably non-pathogenic.

Sickness Rates in Cold Climates.—These have probably been studied even less than in the tropics. According to Lind (1774), " An intense degree of cold, if the air is at the same time pure and dry, is productive of few diseases, when seamen are sufficiently cloathed and kept in due exercise." It is almost certain that the man-days lost by sickness are less than in hot climates, and perhaps even less than in the temperate zones, so long as overcrowding is avoided. Probably the bulk of the loss in man-days is made up of upper respiratory infections, and it is a matter for discussion why severe cold *per se* should be ineffectual in precipitating such types of illness, whereas the winter incidence in temperate or temperate-frigid regions should rise. Very many other epidemiological factors besides cold are concerned. Few nowadays would agree with the opinion expressed by Kane that " An arctic night and an arctic day age a man more harshly than a year anywhere else in all this weary world."

Psychological Effect of Prolonged Residence in the Cold.—This subject arises out of the question, already touched upon, as to the possible deterioration in efficiency in cold environments. As in the case of the tropics, cold alone does not enter so much into the mood and personality changes which occur in the far north, as the total situation—boredom, isolation, long hours of darkness, monotony of diet, etc. During the war it was sometimes asserted that personnel stood up better to conditions in the extreme north than in the tropics—not only as regards their physical health, but also in respect of morale. Nevertheless, troops in the arctic were liable to show psychiatric changes. The Germans occupying the extreme north of Norway described a sort of " barrack fever," mainly psychiatric in its manifestations. In Finland they used to speak of a " spring-tiredness " which they ascribed to deprivation of sunlight and which disappeared in the summer. This condition is comparable with the Russian " light-hunger," or " sun-thirst."

Dr. F. A. Cook of polar notoriety spoke of " the awful mental depression affecting arctic explorers, the suppression of bodily functions, somnolence, melancholia, and the desperation of the sufferers." Burton's *Anatomy of Melancholy* also referred to the depression of those dwelling in " Iceland, Muscovy, or under the Pole itself."

In these high latitudes the mood-changes usually comprise depression, and are different in clinical appearance from the tropical neuroses. Even the arctic psychoses seem to comprise an undue proportion of melancholia. Otherwise there are points of resemblance between some of the alcoholic

outbursts common both in the arctic and in the tropics: the queer specific psychoses of the north (*piblokto*, *miryachet*, *wihtiko*) are not very unlike some of the mental disorders of the tropical indigenes already mentioned.

Effects of Sudden Change from one Climatic Extreme to Another

Here is a situation which may be of even greater moment than prolonged residence in one type of climate. While it is well realized that a change of air or of climate proves refreshing and beneficial, physically and mentally, the change must obviously entail not too great a difference. As already stated, acclimatization to the heat entails one type of physiological adjustment; and to the cold another, quite different. Too abrupt a transition to another climate brings about a certain strain, which falls chiefly upon the circulation and the heart. Consequently, it is in the debilitated, the aged, the hypertensive, and the arteriopath that these transitions are worst endured.

Barcroft and others (1923) have dealt with the vicissitudes which occur in the blood volume and their probable ill-effects. Bazett too has described the possible role of sudden changes in weather or climate in the ætiology of cardiovascular and archovascular accidents. The subject is by no means a novel one. Hippocrates wrote: "For when an old man has been heated in the head and brain by a large fire, and then comes into the cold and is chilled, or if he leaves the cold for warmth and a large fire, he experiences the same symptoms and has a seizure." In another place he lays down that "it is chiefly the changes of the seasons which produce diseases."

The early records of maritime medicine also contain references to this danger. We find Armstrong (1843) ascribing the premature appearance of old age so common in seafaring people to the extreme vicissitudes of climatic conditions. James Lind in 1774 wrote "it is not the degree of cold in the air which affects health so much, as the sudden changes from heat to cold, or from cold to heat."*

The subject, if not novel, is at least interesting and rather obscure. A few scientific enquiries have been made to correlate meteorological factors with disease incidence, or the periodicity of recurring affections. Ernest Jones (1905) studied figures for the occurrence of apoplexy with the existing weather conditions, but without finding much correlation. Petersen's monograph (1935) upon *The Patient and the Weather* forms an ambitious if not altogether convincing analysis of this subject.

Palmer (1730), working in Boston, also attempted to associate the occurrence of cerebral hæmorrhage with seasonal changes in weather.

Personnel Selection and Rejection for Foreign Residence

One of the most promising methods whereby successful habitation of unpropitious regions might be effected would be by the judicious elimination at home of those unfitted to live either in extremely cold or extremely hot climates, coupled with the selection of those pre-eminently suited. Unfortunately it cannot yet be said that our methods of selection and rejection rest upon a sure basis, though we are more advanced in the matter than we were. The problem is not insoluble; nor is it even a particularly difficult one, and promising lines of investigation can already be clearly discerned.

In the first place, some attention is deserving to the subject which has been termed by Minding "nosochthonology," or the study of the influences of geo-physical environment upon the human. This question has been discussed and debated for centuries, indeed ever since the days of Hippocrates, who was probably the first to discern a relationship between geography, climate, and the personality of the inhabitants. "For when the seasons exhibit the most violent and frequent changes," he taught, "there the land is wild and uneven. But when the seasons do not alter much the land is apt to be more uniform and so too will be the inhabitants. For the denizens of these regions ultimately come to resemble the lands in which they are reared." The same theme was advanced in the sixteenth century by the philosopher-economist, Jean Bodin. But it is Montesquieu whom we particularly associate with this belief. He contrasted the habits and temperaments of peoples dwelling in the north from those of the south, drawing an analogy with the contrasting climates. Northern peoples campaigning to a southern region, he claimed, did not perform such exploits as the local populace. Climate also affected the intellect, and in hot parts of the world he finds . . . "aucune curiosité, aucune noble entreprise, aucun sentiment genereux; les inclinations y seront toutes passives; la paresse y fera le bonheur; la plupart des chatiments y seront moins difficiles a soutenir que l'action de l'âme, et la servitude moins insupportable que la force d'esprit qui est necessaire pour se conduire soi-même." †

* "Transition, especially if quick, from cold to extreme hot weather, generally causes a plethoric disposition. The signs are, a pain and giddiness of the head, a heaviness and dullness of the eyes, which sometimes appear slightly inflamed; there is usually a sense of fullness and weight in the breast, the pulse becoming quick and oppressed. Some, at this season, are seized with fevers; a few with fluxes. In such cases, blood-letting is plainly indicated."

† Montesquieu's views upon English climate and character are of interest: "Ce caractère (d'impatience), dans une nation libre, seroit très propre de deconcerter les projets de la tyrannie, qui est toujours lente et foible dans ces commencements, comme elle est prompte et vive dans sa fin; que ne montre d'abord qu'une main pour sécourir, et apprime ensuite avec une infinité de bras. La servitude commence toujours par le sommeil. Mais un peuple qui n'a de repos dans aucune situation, qui se tâte sans cesse, et trouve tous les endroits douloureux ne pourroit guère s'endormir. La politique est une lime sourde qui use et qui parvient lentiment à sa fin. Or les hommes dont nous venons de parler ne pourrvient soutenir les lenteurs, les détails, le sang-froid des négociations; ils y reussiroient souvent moins que toute autre nation; *et ils perdroient, par leurs traités ce qu'ils auroient obtenir par leurs armes.*"

His great protagonist was David Hume, whose essay on *National Character* asserts, " Nor do I think that men owe anything of their temper or genius to the air, food or climate . . . Physical causes have no discernible operation on the human mind."

It is obvious that much individual variability exists in suitability or otherwise for service or residence abroad under climatic extremes. While some subjects adjust themselves well both physically and mentally, others completely fail. Any system of " artificial acclimatization " practised at home or in a temperate climate would, therefore, have the additional merit of acting as a filter, isolating those who are incapable of adjustment. The system of acclimatization formerly carried out in the Rand gold mines has already been mentioned, and its role as a selection process noted as an important side-effect.

The status of personnel selection for tropical or subarctic residence does not yet rest upon very sure or scientific foundations. A strict medical examination, and perhaps a preliminary psychiatric interview, might probably identify those who are obviously unsuited, but there will be many potential misfits who will pass these preliminary tests.

Physical Health.—A number of minor or chronic maladies become much exaggerated in unpropitious climatic environments. One would, therefore, look askance at a candidate with mild arthritis, chronic bronchitis, arrested tubercle, or some intractable skin disorder. Though able to continue at useful work in temperate climates, such persons might well become incapacitated in extreme heat or intense cold. The initial medical examination would, therefore, be an unusually strict one, and the standards for acceptance set very high.

Psychological Aspects.—It might be expected that individuals who elect to go abroad and work in isolated and inclement regions will stand up better to the conditions than those, like service personnel, who are conscripted and sent abroad irrespective of their inclinations. Broadly speaking this is true, and the breakdown rate is probably much lower in civilians than in soldiers and sailors (conscripts, not regulars). Missionaries show a relatively minor rate of neurotic illness compared with commercial employees and civil servants, but the rate is high enough to cause comment. It must be remembered that there may be very definite psychiatric reasons for volunteering to live and work in the tropics or polar regions which would facilitate and not prevent subsequent breakdown. Certainly psychopaths, both of the inadequate and of the aggressive varieties, are apt to fare badly. The boredom of isolated assignments cannot be well endured by those of poor intellectual calibre or educational status. Alcoholic tendencies should be regarded as an absolute contraindication to employment in the tropics or colder regions. A previous history of a nervous breakdown should also preclude a candidate. In the Services it was found desirable to recommend that none with a bad crime record should be sent to a station where the climate is unpropitious.

There is a good case, therefore, for a preliminary psychiatric interview in selecting candidates, though the psychiatrist himself needs to be carefully chosen, and should be one who himself has experience of the conditions of life abroad.

Age.—Obviously the elderly do not tolerate the extremes of heat and cold as well as the younger adults, whose cardiovascular system is more elastic and adjustable. This especially applies to those who have not lived abroad before under climatic extremes. Nevertheless one should not exaggerate this point, and experience has shown that if the elderly candidate is in robust health, is keen and ready to put up with discomfort, and has been experienced in hardening experiences of other kinds in the past, he may make the grade excellently. Scott's last letter from the South Pole said, " I want to tell you I was not too old for this job (he was 43). It was the younger men who went under first."

Body Build.—Tropical exigencies are less well tolerated by those of pyknic habitus than by the spare or by the tall lean types. When working in humid atmospheres a big man is perhaps at a disadvantage compared with a small one, for both will produce heat in proportion to their weight and dissipate it according to the ratio of body weight to surface area. Such was the case in Robinson's (1942) comparison of two subjects, but Weiner's analysis of over two hundred miners showed only a slight correlation between heat tolerance and surface area. A poor musculature is not a handicap. In the case of cold climates, a generous amount of subcutaneous fat is of benefit short of a pathological obesity with its attendant circulatory strain. Apart from the factor of fat-insulation, big persons on the whole tend to endure cold better than the small, just as the larger mammals are the ones to survive in the arctic. Exceptions occur, of course, as in Scott's party, where they found " strength of will " more significant than physical constitution.

Physical Efficiency Tests.—These might be most helpful if standardized. A step test has proved useful in the selection of recruits, and correlates well with subsequent performance in the heat. The virtues of any selection procedure which reproduces closely the actual conditions of work are obvious, and it should be developed farther.

Pigment.—There is some relationship between the pigmentation of an individual and his tolerance towards tropical life, though few would go all the way with Woodruff (1905), who said that recruits for tropical service should be limited to brunettes of short stature—the Mediterranean type, in fact. This same author tried to demonstrate a predominance of the blond in cooler climates and of dark-skinned in the heat. Regarding sailors as essentially encompassed by a low-temperature environment (which of course is not the case), Woodruff has written "The blond type of man is now and always has been the best sailor. He takes to water like a duck . . . he is the yachtsman of the world, the boat-builder, and rules the sea at the present time." For arctic service, cutaneous pigment is unlikely to influence the selection test, despite Woodruff's beliefs.

But certainly tropical service is not for those who have such congenital defects of pigment as leucodermia. Albinos fare very badly in hot climates, and those rare cases of albinism in coloured people seldom attain adult age. Vitiligo, if sufficiently extensive, is a handicap. Persons who are of excessive or "platinum" blondness, especially if showing a tigroid fundus on ophthalmoscopical examination, are doubtful candidates for the tropics. Even the red-heads are suspect, by virtue of cutaneous intolerance towards the sun's rays. It has been said that the French Foreign Legion used to debar such candidates, but considerations other than photosensitivity might have been in mind.

Possible Biochemical Factors.—Experience both in the tropics and in the far north shows that there are certain rare persons who are conspicuously intolerant of the heat, and others of the cold. Such heat-sensitive and cold-sensitive subjects are not conspicuous to ordinary medical tests; nor do they stand out by virtue of any feature of age, build, or colouring. It would be a convenience, at the very least, if it were possible to devise some test or criterion whereby these rare cases could be identified at home. No such hall-mark is yet known, though a close physiological study is projected of all naval ratings who are invalided from the tropics to the United Kingdom as being heat-sensitive. Alterations in the blood lipoid-phosphorus level and in the suspension stability test have been suspected, but not demonstrated, in such cases. It is possible that some inherent dysfunction of the sweat glands or of chloride metabolism, or both, may be a feature of the heat-sensitive. A fairly wide variation in the chloride content of the sweat is known to occur, but no serious attempt has yet been made to correlate the biochemical with the clinical data. The proportion of eccrine to apocrine glands may be significant in this connexion, as suggested by the known racial differences. Still more likely is a link between the total number and distribution of eccrine glands and heat tolerance. Unreadiness to sweat in hot atmospheres may be a factor in determining heat sensitivity. Thus Borchardt (1934) closed up fifteen subjects for two or three hours in a hot room at 33° C. (91·4° F.) with a relative humidity of 90 per cent. Seven of them sweated much less than the others, and these developed various distressful symptoms, their body temperatures rising considerably. Kuno (1935) regards those hypohidrotic persons as probably unsuited for tropical residence.

There are several possible causes of constitutional deficient sweating; there may be a relative insensitivity of the sweat centres in the hypothalamus, the medulla, or the spinal cord; or the sweat glands themselves may be abnormally sluggish in action or too few in number. With regard to the last point, it is important to note that those very rare persons with congenital absence of sweat glands should be absolutely precluded from the tropics.

Sensitivity towards high temperatures may increase as the result of a previous attack of heat stroke. For this reason, firms usually transfer an employee to the United Kingdom permanently on his recovery from such an illness.

The phenomenon of cold sensitivity exists in a small proportion of the population. Such display considerable distress and even syncope when exposed to low temperatures which would not incommode the average. Horton and Roth (1937) believe they can detect such cases in the laboratory. Five minutes' soaking of the hands in water at 8 to 10° C. (46·4 to 50° F.) will bring about flushing of the face, rapid pulse, and a fall in blood pressure. They believe that such can be desensitized in either of two ways: (1) by immersing the hand in water at 10° C. (50° F.) for one or two minutes twice a day for three or four weeks; or (2) by the subcutaneous injection of 0·1 mg. of histamine twice a day for two or three weeks.

An acquired sensitivity to cold may develop in those surviving severe exposure—as, for example, sailors who have been immersed for long periods in the sea or who have been adrift in waterlogged boats. A local hypersensitivity to cold is, of course, one of the characteristic sequelæ of immersion foot.

The subject of selection and rejection, in so far as it was illustrated by personal sensitivity to cold, was well expressed a hundred and twenty years ago by Moricheau-Beaupré, whom we have already quoted in full.

Protection Against Extremes of Heat

Johnson (1815) wrote that " man, by the exertion of his mental faculties, can raise up a thousand barriers round him, to obviate the deleterious effects of climate on his constitution." It must be admitted that this science of protection has not yet been prosecuted with sufficient thoroughness or enthusiasm. The pressing exigencies of the war, flinging millions of white men into tropical warfare, considerably stimulated research into those aspects of hygiene, but the war ended with many projects left unanswered. The advisability of continuing these studies scarcely requires emphasis.

Clothing.—One of the chief problems for tropical residents is that of clothing. Herein we can witness a considerable change of front over the course of the past century. We recall the times, not yet beyond living memory, when soldiers campaigned in heavy scarlet uniform, and when sailors wore high-necked uniform with flannel underclothing even in the summer months in the Persian Gulf. Concessions to a scientific protection against the sun were found in solar topees, spine pads, and woollen cummerbunds or cholera belts. It is obvious that tropical dress in those days was influenced by three medico-scientific beliefs, two of which were certainly unsound and the other possibly so. On the one hand it was considered that the major ills of the tropics were due to the direct rays of the sun (rather than simple heat effects). On the other, there were visualized ill-effects from sudden chilling of the abdominal wall (e.g. after sundown, in draughts from evaporated sweat). Thirdly, danger was visualized after the tropical sun had set, and this was freely ascribed to the chill and dank miasmata arising from marshes, lakes, rivers, and swamps.

Nowadays, tropical dress is largely governed by two medico-scientific considerations : protection of the skin against biting, disease-carrying insects ; and avoidance of heat effects. During wartime the first of these assumes the greater importance, in order that man-day wastage from malaria, dengue, and so on may be avoided. Civilian residents within the tropics usually adopt their own methods of protection, and appropriate dress looms less prominently.

The science of clothing advanced more rapidly during the last war years, so that by about 1944 it was possible to enumerate a large number of considerations which had to be filled by an ideal fabric. There are at least twelve points which come up for discussion.

1. The textile should impose the least possible physiological burden, so that avoidable heat-effects may be countered. This virtually means that the textile should be of the lightest possible weight. Hence loosely woven cottons or closely woven silk, nylon, cotton, or mixtures thereof are indicated. The degree of physiological load is readily tested by the use of human subjects working on a treadmill at a standard task, in a hot room where temperature, humidity, and air movement are established. The subject works nude, and afterwards he wears the various experimental garments to be tested. Rectal and skin temperatures, heart rate, blood pressure, and volume of sweat loss are recorded.

2. The cutaneous surfaces should be protected, to some extent at least, against the direct rays of the sun. That is to say, until a person is tanned and acclimatized there should not be an undue exposure of too great a skin-area. This consideration influences the pattern and design rather than the material for clothing.

3. Both the design and the textile should be comfortable. That is to say, the clothing should be loose, rather than tight ; high collars and other such features may prove undesirable. During the war this was largely a problem of the comparative merits of shorts versus long trousers ; bush shirts versus blouses ; two-piece as opposed to one-piece garments. There is some merit, too, in a slight starching of a tropical garment so as to produce a sort of bellows action. It is highly important to avoid as far as possible any constricting band, e.g. a belt, which is liable to produce a severe local crop of prickly heat. The material itself should be smooth and " cool " to the touch, and when impregnated with sweat should not cling clammily to the skin. In this last respect, loosely woven materials are best.

4. The textile should be impermeable to the bites of stinging insects, such as mosquitoes. This is a quality which can be tested in a laboratory, though it must be borne in mind that mosquitoes differ with regard to the length and delicacy of their probosces. Tightly woven cotton, silk, or artificial silk fabrics are the best protection.

5. The material should, if possible, be water-repellent. There is a risk that this quality may be gained by chemical proofing in such a way as to prevent the evaporative cooling of sweat from the body. There are certain fabrics, however, which combine a fair degree of water-repellency with adequate ventilation, so that evaporation is not inhibited and no chemical treatment is required.

6. The colouring of the garment should be such as to reflect the heat-rays of the sun. For this reason whites are best. Woodruff some years ago (1905) advocated the use of black undergarments (or linings) beneath an outer white layer.

For service personnel in wartime, other considerations come into play.

7. The design of the dress (uniform) should be such that there are no avoidable gaps or openings which might permit the entry of such parasitic pests as ticks, mites (vectors of typhus), or of leeches.

8. The material should be durable and be able to stand up not only against very hard wear but also against the tropical deterioration due to moulds and fungi. At the same time the textile should not be unduly friable,

and here the closely woven stuffs are at a relative disadvantage.

9. The textile should be sufficiently thermal-resistant to protect the skin against flash burns.

10. The colour of the fabric should not be determined solely by its reflective properties, for visibility to enemy aircraft must be considered. Hence whites, ideal in many respects, are perhaps contraindicated. A compromise may have to be reached, as in the jungle green of S.E.A.C. personnel

11. Lastly, the textile should be such that it is capable of taking up various chemical substances, of an anti-gas, insect-repellent, flash-proofing, or water-resistant character.

By the end of 1944 it seemed as though the tussle between loose cellular weaves and tightly woven fabrics was being solved in favour of the latter. This was largely due to the priority placed upon anti-malarial measures, and insect-permeability dominated the counsels. But early in 1945 the situation was shifting slightly ; the efficacy, and the increased availability of the newer insect repellents (dimethyl—dibutyl—phthalate), the organized employment of suppressive mepacrine, made it less essential to insist upon an impermeable textile. There were the beginnings of a swing of the pendulum back to the cooler, cheaper, and more comfortable loose-weaves. These latter have yet another advantage ; they are somewhat more heat-retaining, so that if there is a sudden drop in temperature they are rather better than the tightly woven fabrics (provided there is but little air movement).

Housing

The problem of the ideal type of architecture suitable for tropical residents has, of course, many medical aspects, but the problem lies outside the scope of this review. One or two important features may be mentioned, without undue elaboration. With wartime exigencies, and sudden entry of large numbers of white personnel, the difficulties increase.

1. There is a wide variation in the style of tropical dwellings, including selection of building materials, between the differing nations. Thus, British colonial architecture differs in many particulars from the American preferences, and more so from the Portuguese, French, and Spanish styles adopted in their tropical empires. These again differ from the models selected by indigenous peoples. Herein an outsider might see the advantage to be gained by pooling and exchanging experiences. Medical opinion upon the purely hygienic characteristics should not be a matter of serious dispute.

2. The advantages of air-conditioning in houses, offices, and factories appear obvious, though medical details as to optimum standards etc. need perhaps to be studied further.

3. Fly-screening of buildings may be a matter of considerable importance, especially in barracks and camps, as the Americans demonstrated so clearly during the war 1939–45. The matter is by no means beyond debate and there is at times a considerable prejudice against such a practice by some tropical dwellers.

4. The correct siting of European-occupied dwellings and offices with relation to indigenous habitations may be a very delicate problem. There is an *a priori* case for putting white and coloured dwellings at a respectable distance from each other, because of the reservoir of infection which is apt to be constituted by the coloured folk, and especially the young ones. Such a policy of segregation or separation, albeit medically desirable, is apt seriously to offend official policies of a "non-discrimination" character.

Food and Drink

Text-books of tropical hygiene traditionally recommend a modification of the alimentary habits usual in the temperate zone. A reduced global intake, a relative reduction in high calorific foodstuffs, an avoidance of highly spiced dishes, and an economy in the use of condiments are the conventional pieces of advice. But common experience shows how often such counsels are flouted, and apparently with impunity. During the last war the tendency was for troops in the tropics to adhere as closely as possible to the sort of diet they would select at home. Sailors were particular offenders in this respect, and they insisted, as far as lay within their powers, on hot roast joints, potatoes, greens, and suet puddings even in the Persian Gulf in summer time. Their conservative tastes led them to eschew fish, salads, and local vegetables. And yet it was difficult to demonstrate any detriment which they suffered as a consequence, save possibly a heightened proclivity to prickly heat. Partly, of course, this peculiar dietary has a sociological explanation, and daily roast meat might represent to them a measure of social superiority beyond their civilian status.

But even the tropical civil resident has his own peculiar predilections, and we find some highly seasoned dishes much in favour in the tropics, e.g. the palm-oil chop of West Africa, and the curries of the Far East. Just how such a choice can be excused on dietetic, hygienic, or physiological grounds is difficult to say. Similarly, the consumption of alcohol in excess of what is the habit in temperate zones is not only common but is often rationalized as a means of preventing fever.

The dietary habits of the indigenous coloured population are usually very different from that of the white settler, but it cannot be argued that the former are necessarily more rational or hygienic than the latter, as poverty and inadequate supply

play so large a part in native diets. One can hardly deny that there are still many gaps in our knowledge of tropical dietetics.

We may count among the few great means whereby tropical residence has been facilitated in recent years, first, the use of the refrigerator, and secondly the development of canned foodstuffs. With these two innovations the white settler is able to choose his own foodstuffs, to be independent of the tainted or dubious local supplies; and to maintain his stocks pure and edible for long periods of time. These accomplishments can be attributed largely to the largesse and organizing ability of America, as well as to their higher national standards of cleanliness. Two other practices with regard to communal feeding in the tropics stand to their credit. When American forces came to West Africa during the war, they pushed fly-screening to a degree of perfection probably not witnessed before in that part of the world. The jaded European settler in the tropics too often gets tired of attempting fly-control, and lowers his hygienic standards as time passes. The other achievement was the routine search for, and elimination of, all dysentery-carriers among the natives who handled, cooked, or served foodstuffs. The task was a tremendous one, but proved well worth while.

It is probably true to say that the war years emphasized that on the whole people drink too little fluid in the tropics. The subjective sensation of thirst apparently does not provide a sure index of the presence or absence of dehydration. A water-intake over and above what seems to be required to assuage thirst is necessary to maintain maximum physiological and psychical efficiency. Enormous quantities of fluid may be required to offset the sweat loss, and in such cases it is often necessary to take deliberate steps to replace salt loss. Many minor forms of ill-health and fatigue, short of the well-known clinical picture of cramps and prostration, have been ascribed to a mild degree of salt and water depletion. The need for a large intake of water is even greater when drugs or medicines are being taken which are eliminated by the kidneys. An outstanding example is the danger of anuria from the use of sulpha drugs in the tropics unless very great amounts of fluids are also ingested. War experience in the desert has also shown that wounded men were more liable to shock and an inadequate resistance against infection if water-intake was not high.

The question arises whether the provision of iced water ready to hand in homes, offices, factories, etc., is the optimum method of avoiding dehydration in the tropics. Though this habit is deeply engrained in American life, it is debatable whether it is physiologically sound. Lesser amounts of iced water are necessary to relieve thirst than of water which is merely cool or tepid. As thirst is known to be an unreliable guide in the question of hydration, it is possible that the iced water habit may allow minor degrees of dehydration to exist, without any subjective feeling of dry mouth or thirstiness.

The question of alcohol in the tropics—whether its effect is more or less deleterious than in cool climates, or equally so—is at present a matter of prejudice and guess-work rather than scientific knowledge. There is scope for controlled observation here, and an authoritative pronouncement is desirable.

Hours of Work: Seasonal Leave

Long experience has at last taught that the hours of work in tropical regions should be different from those practised at home; and that a mid-day break of some hours as practised by the native population has much in its favour. Furthermore, trading companies have learned that it pays to permit, or insist upon, their employees taking long holidays at home every year or two.

As long ago as 1905 Woodruff was writing on the need for curtailing the period of service in unpropitious climates, and the necessity for periodic breaks. He quoted the U.S. Naval practice in reducing the term of commission to two years at Cavite. The French served three years in the best of their colonies, but only two years in the less comfortable regions, and in the worst parts of Africa only twenty months. Woodruff quoted the following opinion laid down by the Inspector-General of the Philippines: "Few men in their third year of continuous service are in their normal condition of physical or mental vigor. This statement will be confirmed almost unanimously by medical officers who have served in the Philippines. It is further believed that a third year of continuous service will result in so great an increase in the number of officers invalided home, or who return to the States broken in health, requiring months of leave and rest for recuperation, that no economy to the government will result. If one could break the period by a trip to the States for a few months, or could spend the hot seasons in the mountains, it might be different. Out of consideration for the almost unanimous wishes of officers affected, and in consideration of what is firmly believed to be for the best interests of the government, it is recommended that the duration of service in the Philippines for all officers be made two years."

So far, however, all such recommendations have been based upon a combination of empiricism and unscientific observation. There can be no doubt that planned studies of industrial human efficiency could be made in the field and in the experimental

psychological laboratory to determine such important points as : (*a*) the optimum length of a working day ; (*b*) the correct spacing of working hours in relation to periods of rest throughout the day ; (*c*) the most desirable times for taking meals, in relation both to rest periods and to working shifts ; (*d*) the number of working hours per week ; (*e*) the value of frequent spells in the cool (up country or at an altitude) and the optimum duration and periodicity of such spells ; (*f*) the question of seasonal leave.

Exercise

It is usual to advise physical exercise to be taken only in the cool of the day or after sunset. Early morning exercise is said to have the disadvantage that heat may be " stoked up " in such a way as to cause the body temperature to remain at an unduly high level for the rest of the day. As stated earlier, we do not altogether understand to what heights the body temperature can rise in tropical residents without morbid consequences. We recall that laboratory tests have shown that rectal temperature rises at a stage before psychological inefficiency begins to show itself. On the whole it is possible that many white settlers in the tropics indulge in an amount of exercise which is unnecessary, possibly even deleterious. Certainly there is a striking contrast between the habits of many native dwellers within the tropics and those that come to live among them. Which habit is biologically the sounder is a matter of opinion.

Air-Conditioning

As a means of maintaining health and efficiency in the tropics, the widespread use of air-conditioning in residences and places of work promises much. Although the initial outlay may be great, the enhancement in working output, in comfort, and reduced sickness-rate may easily prove to outweigh the expense. But up to now there is not enough evidence from industry to demonstrate clearly these suggested advantages from the use of air-conditioning within the tropics. The analogy of warships, both in the Royal Navy and the United States Navy, is promising, where greater comfort, less minor illness, and increased efficiency are recognized to be the rule in compartments where air-conditioning has been installed. The lesson has been particularly striking in the case of submarines serving in tropical waters. In the case of hospitals the benefits of air-conditioned operating theatres are obvious, for the risk of producing unhealthy rises in the body temperature of the patient is ordinarily not inconsiderable. Wards where febrile patients are nursed may also with advantage be cooled, as was found when scrub typhus was treated near the front line in Burma. Should air-conditioning come into favour in the tropics a number of medical problems will arise. In a building or bungalow it may be feasible to air-condition one room only, and it will then be necessary to decide whether it is better to cool a bedroom—and so ensure a restful night's sleep—or an office or compartment where work is prosecuted throughout the day.

The optimum temperature and humidity levels need to be carefully determined with reference to the conditions of the ambient air. Abrupt transition from the heat of the outside atmosphere to the interior of a cold-storage room has been known to bring about what is called " cold shock " or " cold stroke." Possibly this risk has been exaggerated, but something similar might occur with personnel passing frequently from the outside heat into an air-conditioned room, and *vice versa*. If the atmosphere of an air-conditioned compartment is kept too dry, there may result an uncomfortable and an unhealthy condition within the mucous membranes of the upper respiratory passages. We know little of any possible ill-effect upon the resistance to bacterial and viral infections of frequent changes from one kind of climate to another ; or whether such changes affect the speed and completeness of acclimatization. It was said of the air-conditioned wards in the jungle hospitals that the patients were more comfortable, but that the nursing and medical staff who came and went were less appreciative.

There is a hypothetical risk, at any rate, that the fewer renewals of air within a cooled compartment may increase the incidence of airborne disease. The virulence of any pathogenic organisms might also be enhanced just as the relative immunity of the occupants might conceivably be decreased. Obviously such possibilities must be envisaged and checked, and if necessary chemical disinfectors incorporated with the ventilating system.

Certainly there has been at times a tendency to keep the temperature too low in some air-conditioned rooms. Perhaps an effective temperature of 78° F. is low enough when the atmosphere temperature is very high. Others would advocate no greater difference than 10° F. between the untreated and treated air, but this difference is probably too little and the rule too rigid. Mayer and Fittz have devised a formula for computing the optimum temperature.

The future of air-conditioning in a tropical country like India which is developing its industries may be enormous. We are reminded of a dictum made by Lawrence Lowell : " It is hardly an

exaggeration to summarize the history of 400 years by saying that the leading idea of a conquering nation in relation to the conquered was, in 1600, to change their religion; in 1700 to change their trade; in 1800 to change their laws; and in 1900 to change their drainage." Perhaps we could add, " in 2000 to change their climate."

Protection Against Direct Rays of the Sun

This, briefly, comprises the scientific utilization of adequate shade, correct clothing, sun-tan, and the wearing of dark glasses for the eyes.

Modern conceptions of the ill-effects of insolation are of interest especially as there has been some change in our beliefs. As already mentioned, the bogy of sunstroke has been laid, and it is known that this disorder is none other than heat stroke. The true morbid effects of injudicious and undue exposure of the skin surface are now better understood, as well as the mechanism of pigmentation of the skin. The recent valuable review on the physiological effects of sunlight on man by Blum (1945) should be mentioned. According to the author a white skin reflects about 45 per cent. of sunlight as compared with 16 per cent. by a black skin. This means that, though the negro's integument is less sensitive than a white man's to solar radiation, the absorption of heat is greater. The negro's survival in the tropics does not seem to be particularly due to his colouring.

Wartime experience has shown up one or two changes in social habits and prejudices. In the tropics the overclothing of the last century has given way to a cult of nudity, whereby service personnel now seek every opportunity of working and resting with the heads and torsos exposed. The development of a sunburned surface seems to be the first desideratum; secondly a mild " tonic " effect is claimed and an illusion of well-being and vigour; thirdly, a certain narcissistic self-display is not to be overlooked. The claimed health-giving effects of sun-tanned nudity during the war were difficult if not impossible to demonstrate, except in so far as it distinctly reduced the incidence of prickly heat, secondary septic infections of the skin, and also fungus disorders of the feet, ears, etc. To offset these advantages there are the possible risks of producing general tissue-reactions, fatigue, and lassitude, of lighting up latent foci of tubercle, and —remotely—of a possible carcinogenetic effect.

Another interesting fad or fashion in modern tropical life is the widespread popularity of sun glasses. Although without doubt tinted glasses, especially of the polaroid variety, protect the retina against tropical glare, especially when reflected off water or white sand, there is a risk of lowering the photo-sensitivity of the eyes by their unnecessary and indiscriminate use. They are often worn as articles of sheer adornment (e.g. by coloured troops), as a protection against unsightly wrinkles around the eyes (by women residents), because of a neurosis (by victims of anxiety, or of lack of confidence), or as an outward and visible sign of a delicate nurture (as in Eurasians and Levantines). These points are borne out by the not uncommon observation that glasses are often worn indoors and after sundown.

Artificial protection of unshaded skin against the sun's rays was experimentally tested during the war by a variety of substances. Oily, fatty, and greasy media were found in the tropics to do more harm than good, for there was a tendency for the skin to become " fried." Preparations containing tannin were of greater service, as a certain degree of keratinization was produced. Benefit also followed the use of pigmented washes containing flavine or permanganate of potash.

While the pendulum is still swinging back and forth between sedulous self-exclusion from the sun and a kind of fanatical sun-worship, it is difficult to lay down authoritative rules for the tropics. Common-sense suggests, as usual, the happy mean.

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BOOK REVIEW

MICRO-DIFFUSION ANALYSIS AND VOLUMETRIC ERROR

By Edward J. Conway, M.B., D.Sc.

(Crosby, Lockwood and Son, Ltd. London. 1947. Pp. 357. 55 illus. Price 21*s*.)

One of the most important advances in biochemical analysis in the past fifteen years has been the development of the so-called " ultramicro " or " drop-scale " methods. These make it possible to work with weights of a few microgrammes of material and with volumes of a few cubic millimetres. Prof. Conway, who has been a prominent worker in this field, presents in his book an important aspect of it. The microdiffusion method developed by him is both elegant and simple. A gaseous reaction product is allowed to diffuse (usually at room temperature) from an annular space into an inner chamber charged with a suitable absorbent. It can then be determined by any method, volumetric, colorimetric, or gravimetric, which can be adapted to the ultramicro scale. In theory at least, any reaction producing a reactive gaseous product could be followed by microdiffusion methods. The simplicity and accuracy of the Conway methods are outstanding, while the range of utility of the technique can be gauged by the methods at present available. These comprise ammonia and aliphatic amines (including ultramicro Kjeldahl methods), urea, adenine compounds, nitrates, amides, halogens and halides, acetone, lactic acid, ethyl alcohol, the amino acid threonine, carbon monoxide, carbon dioxide, and glucose. A recent addition, which may be of considerable importance in the future, is a vapour pressure determination on the ultramicro scale.

The book is divided into three sections. The first deals with the general theory of micro-diffusion analyses, both from the theoretical and experimental aspects. It provides a secure foundation for the analytical methods described, with full experimental details in the second section. Although the greater part of this section is devoted to the Conway methods, microdiffusion techniques of other workers are also given in detail. The third section provides an admirable discussion of error in volumetric analysis. The emphasis throughout is on statistical methods of evaluation of error, and the whole section is a most valuable contribution to the theory of analytical chemistry. It stands in vivid contrast to the vague generalities current in many text-books of analysis.

Major points of criticism are few. The symbols χ and μg are used interchangeably for the microgramme, apparently at random. The chapter on micro-burettes does not mention the micrometer syringe, which many workers prefer to any of the apparatus described. It is stated rather dogmatically (p. 68) that " the Lambert-Beer law . . . . is not valid on the presence of proteins." This is certainly not true ; many dyes obey the Lambert-Beer law over a wide concentration range in the presence of serum proteins. The term " monochromatic radiation " is somewhat loosely applied to the relatively wide wave bands isolated by filters, and it is not made clear that the Lambert-Beer law is only strictly valid for monochromatic light in the physical sense. The principles governing the choice of light filters are given very slight treatment. Many would feel that, in view of the almost universal use of photoelectric absorptiometers today, the space given to visual instruments is disproportionately large. Misprints are few and none is misleading.

This book is the first, to the reviewer's knowledge, to give a detailed account of ultramicro methods, and it is to be hoped that it will introduce the techniques and the principles behind them to many who will find them of use in their own problems. *C. J. O. R. M.*

BRITISH AND FOREIGN OFFICIAL PUBLICATIONS

THE ROAD BACK TO HEALTH :
THE STORY OF MEDICAL REHABILITATION

(H.M.S.O. 1947. Pp. 28. Price 6*d*.)

Whatever one's reactions to blasts of propaganda, there can be few more popular ports of call for the occasional visitor to London than the Retail Department of H.M. Stationery Office in Kingsway, and it would indeed be a hardened sales-resistant misanthrope who left without the attractive sixpennyworth of excellently reproduced press photographs entitled *The Road Back to Health* (S.O. Code No. 32–371) presented in a sky-blue cover with the subtitle *The Story of Medical Rehabilitation*. It will be to the hypersensitive alone that the first three words, *The Road Back*, are slightly reminiscent of *Der Weg Zuruck*, but the subtitle is open to more serious criticism, for the frontispiece is a full-page illustration of a patient in the inevitable dressing gown, toying with basket work reposing on the beginnings of a rug, over a caption which can only mean that he is in the process of recovery from pneumonectomy. Thereafter the volume is devoted to surgical rehabilitation as opposed to medical rehabilitation, though reference is made to the uses of physiotherapy in bronchitis, asthma, and pneumonia.

In his foreword the Minister points out that the book is intended for hospital authorities, family doctors, welfare workers, Trade Union officials, and voluntary bodies, and expresses the hope that members of the public who read this book will realize what is being done and also what is to follow.

The story of surgical rehabilitation is well told and the relationship of physiotherapy, remedial exercise, occupational and " diversional " therapy, is clearly presented, as is also the role of the almoner and welfare worker.

More could possibly be said, even in a brief résumé, confining its attention to schemes sponsored by the Ministry of Health, about the development of industry round special sub-standard communities, as exemplified for instance by village settlements ; in this connexion it is particularly necessary to keep in view the relationship between diversional therapy and true rehabilitation, with its economic as well as remedial implications.

L. B. Stott.

THE EFFECTS OF ALIPHATIC NITROUS AND NITRIC ACID ESTERS ON THE PHYSIOLOGICAL FUNCTIONS WITH SPECIAL REFERENCE TO THEIR CHEMICAL CONSTITUTION

W. F. Von Oettingen. *National Institute of Health Bulletin, No.* 186. Washington. 1946. Pp. 66. Refs. 228

The pharmacological and toxicological actions of aliphatic nitrous acid esters (alkyl nitrites) are characterized by a fall of the blood pressure due to peripheral vasodilatation, acceleration of the pulse rate, and, if exposure is sufficient, by the formation of methæmoglobin. The fall of the blood pressure is due to peripheral vasodilatation, which is bound to the grouping R–ONO. The properties of ethyl nitrite and amyl nitrite are described in detail.

Aliphatic nitric acid esters are explosive and the properties of methyl nitrate, ethyl nitrate, ethylene glycol mononitrate, ethylene glycol dinitrate, glycerol dinitrate, glycerol trinitrate, erythritol tetranitrate, pentærythritol tetranitrate, mannitol hexanitrate, mannitol pentanitrate, 1, 4, 3, 6–dianhydromannitol–2, 5–dinitrate are reviewed. All cause lowering of the blood pressure and methæmoglobinæmia.

The mechanism of the circulatory changes has only been closely studied for amyl nitrite and glycerol trinitrate. An extensive review of pharmacological literature is given. Both cause an increase in pulse rate and lowering of blood pressure. Small doses which do not affect the blood pressure increase the cardiac output. The pressure on the pulmonary artery increases (and may lead to pulmonary œdema). The coronary arteries are dilated. Little information is available about the effects of continued exposure.

Methæmoglobin resulting from the action of aliphatic nitrous and nitric acid esters is of importance in the acute toxicity of these compounds, especially of those—such as ethylene glycol dinitrate—with which this effect is marked. This methæmoglobinæmia may lead to an anoxic condition in vital organs, especially the brain and the heart muscle.

T. A. Lloyd Davies.

THE TOXICITY AND POTENTIAL DANGERS OF METHYL BROMIDE WITH SPECIAL REFERENCE TO ITS USE IN THE CHEMICAL INDUSTRY, IN FIRE EXTINGUISHERS, AND IN FUMIGATION

W. F. Von Oettingen. *National Institute of Health Bulletin, No.* 185. Washington. 1946. Pp. 37. Refs. 54.

Methyl bromide (monobromomethane CH_3Br) is a colourless gas which solidifies at −93° C. and boils at 4·5° C. On a large scale methyl bromide is made by heating sodium bromide, methanol, and sulphuric acid to 130° C. in a closed process. Methyl bromide-air mixtures are incapable of ignition but at raised temperatures decompose to carbon dioxide and carbon monoxide, hydrogen bromide and bromine, and in some circumstances to carbon oxybromide. The halide lamp is unreliable for detection of methyl bromide below 50 parts per million. Reliable chemical methods of estimation are described.

Methyl bromide is used as a methylating agent, in fire extinguishers, as a fumigant and insecticide. Absorption is nearly always through the lung but may, if swallowed, be through the gastrointestinal tract. The amount absorbed through the skin is disputed. Methyl bromide is distributed throughout the body and stored in tissues rich in lipoid material. Excretion, which is slow, is through the lungs and kidneys. Its toxicity for animals has been widely studied, and in general the symptomatology and pathology are similar to that in man. Deaths from acute poisoning result from its irritant effect on the lungs and from chronic poisoning from changes in the central nervous system. Published reports of experimental findings in dogs, cats, rabbits, mice, rats, guinea pigs, and monkeys are reviewed.

Since 1899, 28 cases of fatal methyl bromide poisoning in the human subject have been reported. Fourteen occurred in chemical or filling operations, 4 from the use of methyl bromide as a fumigant, 10 from the use of fire extinguishers. In addition, 150 cases of non-fatal poisoning, including 6 of systemic poisoning with skin injury, have been recorded. In addition, 32 instances of skin injury have been reported. The literature is reviewed in detail, and a complete list of authors and references given. The fatal cases resulted from exposure to relatively high concentrations (varying from 8,600 to 60,000 parts per million). In general, the onset of toxic symptoms is delayed : the latent period is usually from 4 to 6 hours but may be as short as 2 hours or as long as 48. Early symptoms of fatal poisoning are headache, visual disturbance, nausea, vomiting. Other symptoms, such as smarting of the eyes, skin irritation, listlessness, vertigo, and tremor, may occur first. Tremors and twitching develop into epileptiform convulsions; and, rarely, convulsions or unconsciousness may be the first sign. Cyanosis results from pulmonary œdema ; fever is frequent, and heart failure supervenes. In view of the rapid progress clinical studies are rare, but inconsistent signs are met with in the central nervous system. The serum bromide is markedly raised. The most significant changes are found in the respiratory tract : the trachea and broni are inflamed with blood-stained or purulent exudate, the lungs are hyperæmic and œdematous. The meninges and brain are hyperæmic, and the latter may show petechial hæmorrhages. The brain is frequently œdematous, with ganglionic changes characterized by fatty degeneration, shrinkage, and pyknosis.

The immediate cause of death is the pulmonary injury associated with circulatory failure ; whereas the cerebral changes, though significant for the clinical picture, are less extensive.

The clinical picture of non-fatal poisoning shows great variation. Symptoms have followed exposure to between 100 and 500 of methyl bromide parts per million. Fatigue, blurred or double vision, nausea, and vomiting, are frequent. Inco-ordination with tremors and convulsions are common ; the patellar reflexes are exaggerated, clonus is present, and Babinski's sign is positive. Nearly every type of nervous disturbance has been reported. In contrast with fatal cases, the pulmonary symptoms are comparatively slight. Even moderate poisoning may lead to prolonged illness or permanent injury, commonly characterized by sensory disturbances, weakness, paresthesial and blurred vision. Occasionally

the liver may be enlarged, but more frequently damage to the kidneys is shown by albuminuria. Blood changes give little help in diagnosis. Blood bromide is raised. The greatest reliance must be placed on the neurological examination. With one exception the cerebrospinal fluid has been reported to be of normal constitution and pressure. Exposure to high concentrations (about 8,000 parts per million) of vapour may cause prickling of the skin, erythema, and vesiculation. These injuries occur most frequently where the body is irritated by close-fitting garments. More severe injuries result from splashes, and methyl bromide will penetrate clothes, gloves, and boots. Skin changes result from the toxic effect of methyl bromide on the skin.

Moderate symptoms will disappear on stopping exposure and transferring the patient to fresh air. All contaminated clothing should be removed. The patient should be kept under observation and at rest for 48 hours. Oxygen should be given for cyanosis, and venesection may be indicated if pulmonary œdema develops. Convulsions may be controlled by the barbiturates, but for severe convulsions the inhalation of chloroform and oxygen may be required. Glucose may be administered intravenously if there is enlargement of the liver, but such injections should not be given if there is a risk of pulmonary œdema. Sodium bicarbonate solution has been recommended for cleansing the skin; blisters should be aspirated. The use of tanning agents has been disputed.

The mode of action of methyl bromide has been the subject of much speculation. In cases of acute and fatal poisoning it is open to question whether the pulmonary injury is primary or secondary to the circulatory changes, and whether methyl bromide acts directly on the vascular system. In less acute poisoning, circulatory and respiratory changes may be insignificant, but severe and irreparable damage to the central nervous system is produced. It is generally accepted that the narcotic action of aliphatic narcotics such as chloroform is due to the entire molecule and depends on their lipoid solubility. Whilst the narcotic action of methyl bromide is in accordance with its relatively low solubility, toxic manifestations not shown either by ethyl bromide or chloroform must be due to a different mechanism. Rabbits exposed to methanol vapour or fed with sodium bromide do not show the same changes. Ethyl bromide is relatively non-toxic to rabbits compared with methyl bromide, and the few cases of ethyl bromide poisoning reported have nothing in common with the clinical picture of methyl bromide poisoning. It seems established that alkyl halides such as methyl bromide penetrate the cells and dissolve in the intracellular fluid. If hydrolysis takes place within the cells, bromide ions are liberated and trapped intracellularly. The assumption has been made that under these conditions bromide ions have an unusual action, but at present there is no experimental evidence that this is so. The toxic action of methyl bromide and methyl iodide on the one hand, and the difference between the toxic effect of methyl bromide and ethyl bromide on the other hand, point to the importance of the methyl group in producing the characteristic action of methyl bromide. It may be possible that methyl bromide as well as methyl iodide forms a quaternary ammonium compound with nitrogen enzymes and other biologically important amines. Methyl bromide differs from other aliphatic chlorinated hydrocarbons in having a very weak narcotic action, but after a latent period it produces functional and pathological changes in the brain and basal ganglia. In this it resembles manganese and carbon monoxide, both of which affect the oxygen metabolism in parts of the brain. It is possible that methyl bromide may affect iron-containing pigments and interfere with the catalytic action of hæmoglobin.

Accidents from methyl bromide most frequently result from leaking pipe lines and containers or the bursting of these due to sudden changes in temperature. Joints should be lubricated with soap, and gaskets should be made from soft copper, leather, sheet lead, or hard felt.

Workers must be instructed in the hazards of methyl bromide and told of the need of immediate removal of soiled garments and shoes. An adequate supply of gas masks should be available, and it should be emphasized that rubber and leather gloves offer no protection and may increase the hazard.

As a fire extinguisher, methyl bromide is so dangerous that it should not be used by persons uninstructed in its hazards. Its use in domestic fire extinguishers is unwarrantable, and if fire extinguishers filled with methyl bromide are used the operator should stand to the windward side. The use of methyl bromide fire-extinguishing equipment as on board ship presents many dangers. All containers filled with methyl bromide should be weighed regularly to make sure a leak has not occurred.

The use of methyl bromide as an insecticide for the fumigation of foodstuffs has caused a number of accidents. Unauthorized entrance into freight cars and other places where methyl bromide is being used must be vigorously avoided. If fumigation has been properly performed, no residues which may have deleterious effects if such foods are eaten will remain. Containers of methyl bromide should be stored in cool, well-ventilated places away from inhabited rooms.

T. A. Lloyd Davies.

ABSTRACTS

(The abstracts are divided into the following sections: toxicology; industrial physiology; industrial lung disease; accidents and orthopaedic surgery; general. After each subsection of abstracts follows a list of any articles that may have been noted but not abstracted.)

TOXICOLOGY

British Anti-Lewisite. I. Arsenic Derivatives of Thiol Proteins. II. Dithiol Compounds as Antidotes for Arsenic. III. Arsenic and Thiol Excretion in Animals after Treatment of Lewisite Burns. STOCKEN, L. A., and THOMPSON, R. H. S. (1946). *Biochem. J.*, **40**, 529.

I. Kerateine, obtained by opening up the disulphide groups of keratin to thiol groups by means of potassium cyanide at 38° C., reacts with lewisite in phosphate buffer solution at *p*H 7 to give compounds containing approximately 0·5% of arsenic and reprecipitable at *p*H 4·6. Of this arsenic 84 to 87% remains after a second precipitation. Sodium arsenite similarly gives derivatives of kerateine containing 0·4% of arsenic, but of this only 30 to 35% remains after reprecipitation. Meta-keratin, obtained by atmospheric oxidation of kerateine in neutral solution until the nitroprusside reaction for thiol groups is no longer given, combines with only a very small amount of arsenic, and that probably by absorption. Sodium arsenate gives, as expected on chemical grounds, compounds containing an intermediate percentage of arsenic (mean 0·12%). The thiol groups of kerateine estimated by titration with porphyrindin account for some 75% of the arsenic of the lewisite derivative on the assumption that 1 atom of arsenic combines with 2 thiol groups.

II. "Lewisite oxide" (chlorovinyl arsenoxide) and sodium arsenite combine with British anti-lewisite (BAL, 2 : 3-dimercaptopropanol) to give alkali-stable thioarsenites whose rates of hydrolysis are very much slower than those of corresponding compounds of lewisite with monothiols and proteins. The dithiols are not toxic to the pyruvate oxidase system of brain tissue, and can completely abolish the inhibition of this system caused by lewisite and other arsenicals if present in the proportion of 8·5 molecules of dithiol to 1 molecule of lewisite. BAL, when added 15 minutes after the addition of the lewisite, will even completely reactivate a lewisite-poisoned enzyme system. Kerateine also much reduces the toxicity of lewisite, but monothiols such as cysteine and monothioethylene completely failed to protect the enzyme system against lewisite. *n*-heptane thiol and ββ.-dimercaptodiethyl sulphide were without significant effect, while pentane-1 : 5-dithiol showed only moderate protective action. The compound of BAL with lewisite is almost non-toxic to the enzyme. BAL causes almost complete protection against the effects of lewisite on skin respiration, whereas cysteine and 2-mercaptoethanol completely fail to protect. A survival of 100% is obtained by application of BAL to the skins of rats contaminated 30 minutes earlier with lethal doses of lewisite: monothiols were ineffective, and the sample of toluene-3 : 4-dithiol tried proved to be toxic: hydrogen peroxide treatment was much less effective than BAL. BAL in amounts of 100 to 200 mg. applied to the skin exerts a prophylactic action against a lethal dose of lewisite up to 4 hours later. Similar results were obtained with BAL on lewisite-contaminated guinea-pigs: here treatment of the burn with hydrogen peroxide delayed but did not prevent death. BAL injected intraperitoneally or subcutaneously in saturated aqueous solution also promoted survival (up to 100%) of rats poisoned by intramuscular injection of sodium arsenite or by external application of lewisite. On human subjects BAL prevented vesication by lewisite and phenyldichloroarsine, even when treatment was delayed for 30 minutes after contamination: 2-mercaptoethanol was ineffective. In the rat, BAL is lethal in amounts of 2 to 3 g./kg. body weight applied to the skin, and in amounts of 15 mg./kg. injected intraperitoneally or 113 mg./kg. injected intramuscularly, the symptoms including tremors, severe spasm of the abdominal wall, and death in convulsions. In man 0·5 to 1 c.cm. undiluted BAL applied to the skin of the arm produced a scarlatiniform slightly œdematous rash accompanied by severe tingling, these symptoms disappearing in the course of 4 to 5 hours. No other thiol has been found to be less toxic than BAL. The BAL-lewisite compound injected subcutaneously into rats has a lethal dose of about five times that of lewisite in equivalent arsenic concentration: for the corresponding 2-mercaptoethanol derivative the lethal dose is twice that of lewisite. The absence of late deaths among BAL-treated rats and guinea-pigs lethally contaminated with lewisite suggests that the lewisite-BAL compound does not dissociate in the body with the re-liberation of a toxic arsenic compound.

III. Application of lewisite to the skin of rats led to an excretion in the urine of 2 to 4% of the applied arsenic during the first 24 hours. BAL applied 15 minutes after contamination increased the urinary arsenic excretion fourfold, and applied 1 hour after contamination produced still higher rates of arsenic excretion. No diuresis was observed. BAL did not affect the small excretion of arsenic in the fæces, but prevented the diarrhœa caused by lewisite. On subcutaneous injection of the lewisite-BAL compound, 25% of the arsenic administered was recovered from the urine in the subsequent 48 hours. The retention of arsenic in the skin after lewisite contamination was less in the BAL-treated than in the untreated cases. Subcutaneous injection of BAL dissolved in thiodiglycol gave an extra excretion of thiols in the urine (estimated by titration with iodine) during the subsequent 24 hours, the solvent alone giving rise to no thiol excretion. In

catheterized male rabbits a thiol excretion corresponding to 12 to 14% of the intraperitoneally administered BAL was observed in the 6 hours following the injection. A transient albuminuria occurred, and in one case red blood corpuscles were identified in the urine, but no evidence of serious or permanent damage to the kidney was obtained. *T. R. Parsons.*

Study of 64 Cases of Manganese Poisoning in Chile. Clinical Aspects, Unfitness for Work, and Legal Compensation. (La intoxicación por manganeso en Chile. (Estudio sobre 64 casos.) Aspectos clínicos, incapacidad y reparación médico-legal.) ANSOLA JIMÉNEZ, J., UIBERALL, E., and ESCUDERO, E. (1946). *Prensa méd. argent.*, **33**, 1,684.

Two years ago the authors (*Rev. méd. Chile*, 1944, **72**) reported 75 cases of manganese poisoning in the San Juan Mine, Northern Chile. It was thought strange that all these were among men at this one mine, although several manganese deposits are now being operated in Chile ; but this was explained by the special composition of the ore, the physicochemical characters of the dust, and its concentration in the badly ventilated galleries. The 64 cases considered in the present article appear to be some of those referred to above. Symptoms reported by others have been largely those due to actual organic involvement of the nervous system and to a less degree those of a psychic nature ; in the authors' cases the psychic symptoms dominated the picture in half the number. Of the 64, 30 were under the observation of other medical men. The remaining 34 comprised 5 in an early stage, 4 showing mild symptoms, and 25 seriously affected and unable to work. The last 29 are subdivided into : (*a*) those with acute but transient psychic disorders (5) ; (*b*) those with purely organic symptoms (15) ; and (*c*) those with mixed organic and psychic symptoms (9). All worked underground, where the risk of exposure to the dioxide is much greater than at the surface. None of the 34 died of the poisoning, so no pathological changes could be recorded, but others have reported degeneration in the basal nuclei with minute hæmorrhages, and a hepatitis with jaundice.

Of the authors' patients, 1 was 17 years of age, 9 were in the third decade, 14 in the fourth, 7 in the fifth, and 3 between 51 and 58 years. Alcoholism was not found to increase susceptibility to the poisoning. Analysing the 64 cases, psychic symptoms were observed in 34 (53%), and were chiefly of an excitation type (especially in the early stages)such as incessant movement, singing, dancing, working beyond the stated hours ; some patients exhibited outbursts of temper, others euphoria or ecstasy with outpourings of speech, frequent reiteration, and rapid passage from one subject to another. Neurological symptoms comprised in the early stages frontal and occipital headache and either drowsiness or insomnia ; the pressure of the cerebrospinal fluid was increased. Sialorrhœa was common and sometimes observed first ; weakness, muscular pain, tenderness, and tremors occurred ; there was hoarseness, with monotonous or explosive speech ; a Parkinsonian facies, and " marionette-like " movements with hypertonia, were seen in about half the cases The gait was often shuffling ; the high-stepping " hen walk " described by Jaksch (*Wien. klin. Rdsch.*, 1901, p. 729) was seen only three times, but many patients showed great deliberation in walking and disturbance of equilibrium, particularly evident on turning. Romberg's sign was never seen, but Babinski's response was sometimes extensor, and clonus might be present.

The course varied with the degree of intoxication, but in most cases the psychic disturbances improved and even cleared up in two or three months after cessation of exposure to the poison ; the nervous symptoms persisted longer. Three deaths occurred, but they were due to intercurrent disease. The diagnosis had to be made chiefly from epidemic encephalitis ; this was at times almost impossible : important distinctive points were the sialorrhœa and the euphoria ; the occupation supplied a clue. A sign not hitherto noted was dilatation of the vessels of the fundus oculi. The prognosis as regards the psychic symptoms is good, but that of the cases with Parkinsonism should be very reserved. Slow recovery does occur, but partial incapacitation is often permanent. As to legal compensation the figures given of 47 cases followed up may help : 21 were satisfactorily transferred to other occupations ; 5 were temporarily incapacitated but were able to work again ; 12 were totally and permanently incapacitated ; while 9 are recorded as " healthy " [which presumably means that they were able to do a full day's work at some other occupation]. *H. Harold Scott.*

Tetra-ethyl Lead Poisoning. CASSELLS, D. A. K., and DODDS, E. C. (1946). *Brit. med. J.*, **2**, 681.

Tetra-ethyl lead has been widely used for many years in the oil industry, and its toxic properties are well known. Hitherto cases have not been reported in this country, and the mode of occurrence, along with the symptoms, diagnosis, and treatment, is considered in this article. Tetra-ethyl lead can be absorbed through the intact skin, but is more readily absorbed through the pulmonary epithelium, and it is chiefly from inhalation of vapour that poisoning is liable to occur. The fat-soluble character of the compound allows selective localization in nervous tissue, and poisoning is essentially a central nervous system intoxication.

The risks of tetra-ethyl lead poisoning occurring during manufacture and blending and in the distributive trades are considered. Industrial processes are well controlled, and poisoning is rare and virtually unknown in lead-blending. Operations involving the cleaning of storage tanks which have contained leaded petrol carry a considerable hazard, and cases of poisoning have been reported. During the war the handling, packing, and distribution of petrol containing tetra-ethyl lead noticeably increased in this country, and was carried out under poor conditions. No cases of poisoning resulted, but analysis of urine samples showed that lead was present in such concentration as to point to a possibly hazardous exposure. The accepted safe limit of 1·5 mg. of lead per 10 cubic metres of air for atmospheric concentration was exceeded. Some men showed mild symptoms of intoxication and high urinary lead concentrations when engaged in refinery operations.

In spite of considerable precautionary measures, 25 cases of tetra-ethyl lead poisoning, of varying severity, occurred during the cleaning of tanks, many of which were underground ; 2 of the cases had a fatal ending. Case histories are given for 6 men, and ill effects noted in 19 others. Details of clinical examination, blood counts, and urinary lead concentration are described. The early symptoms were disturbance of sleep and symptoms referable to the alimentary tract, and the classical signs and symptoms of lead poisoning did not occur. With longer or more severe exposure the signs and symptoms progressed to increasing tiredness and loss of body-weight, tremor, muscular weakness and twitching, oddities of behaviour, and evidence of mental

confusion, and then, quite abruptly, came the onset of acute maniacal symptoms with suicidal tendencies, or the occurrence of a convulsion. The diagnosis depends upon the appearance of such symptoms, along with the history of exposure to a severe lead hazard; and the degree of exposure can be estimated by the urinary lead concentration. Tetra-ethyl lead poisoning is unlikely, when symptoms are noted, if the concentration is less than 0·1 mg. per litre. The differential diagnosis is considered. The hazards are well understood, and careful observance of the regulations will prevent poisoning. Treatment is briefly described, and is largely symptomatic. The barbiturates are recommended for sleeplessness. *A. Thelwall-Jones.*

The Pattern of Injuries Produced by the Atomic Bombs at Hiroshima and Nagasaki. WARREN, S., and DRAEGER, R. H. (1946). *Nav. med. Bull., Wash.*, **46**, 1349.

High explosive and atomic bombs share the properties of causing injury by what may be classified as air-blast, water-blast, and solid-blast. The additional and characteristic effects of the atomic bomb result from the liberation of much energy as electromagnetic radiation and neutrons, causing what the authors term "radiation-blast" injuries. It is estimated that at Nagasaki 85,000 were killed or seriously injured and at Hiroshima 160,000; most of these injuries resulted from radiation-blast.

The liberated radiant energy is in part thermal and in part ionizing. Flash burns were common, and secondary fires occurred at a distance from the explosion. Ionizing radiation-blast produces effects similar to those of exposure to *x*-rays. The latent period varied, with the weight of exposure, from hours to weeks. In some cases malaise and vomiting were followed by death, attributed to toxic autolysis of tissue, in a few days; with longer survival, signs appeared of selective damage to bone marrow or gonads. The bone-marrow injury was shown by leucopenia lasting up to 4 weeks and accompanied by mucosal or cutaneous infection, by thrombocytopenia and a hæmorrhagic state reaching a maximum severity in 3 to 6 weeks, and by anæmia appearing later but often progressing slowly to death. Spermatogenesis was often arrested, but the parietes usually screened the ovaries from radiant energy. Epilation was common. *R. Bodley Scott.*

Pyridoxine in Treatment of Radiation Sickness. SHORVON, L. M. (1946). *Brit. J. Radiol.*, **19**, 369.

Radiation sickness varies in intensity with the part of the body treated and the area of exposure. The author reports 24 cases treated by pyridoxine, and, as regards the radiation sickness, claims good results in 22. The beneficial effect on the leucocytes is also stressed. Young (*Amer. J. Roentgen.*, 1936, **35**, 681) strongly recommended injections of liver extract. Pyridoxine is a member of the vitamin B_2 group occurring principally in liver and yeast, which Shorvon found superior in effect to other remedies. Among the 24 cases reported, a patient suffering from Hodgkin's disease was much distressed by radiotherapy and benefited by pyridoxine. In another case "a female aged 60 with a large abdominal mass and secondaries in lungs from ? carcinoma of the tongue previously treated by radium and *x*-rays also suffered from radiation sickness, but was promptly relieved by pyridoxine."

[What benefit was expected from radiotherapy is not discussed.] *Geo. Vilvandré*

Irradiation Sickness: Histamine Effect Treated with Benadryl. A Preliminary Report. LOFSTROM, J. E., and NURNBERGER, C. E. (1946). *Amer. J. Roentgen.*, **56**, 211.

Treatment with "benadryl" (β-dimethylaminoethyl benzhydryl ether hydrochloride) was successful in 18 out of 19 cases of irradiation sickness. The degree of relief varied from one patient to another, but all save one felt well enough to continue their daily *x*-ray treatment without interruption. The authors assume that the success of the benadryl treatment was due to its antihistamine action, since histamine-like bodies develop in the blood of patients undergoing irradiation. In view of the beneficial effect of benadryl in allergic conditions such as urticaria, the authors suggest that irradiation sickness may be an allergic manifestation. The most dramatic results were observed after intravenous injections of 100 mg. of benadryl. The cerebral depression common in patients suffering from malignant disease and often aggravated by *x*-ray therapy may be caused by an increase of histamine bodies in the blood. The marked improvement in the morale of the patients after benadryl therapy seems to confirm this. *A. Orley.*

The Determination of Mercury in Air. BARNES, E. C. (1946). *J. Industr. Hyg.*, **28**, 257.

The paper describes the method used in an Industrial Hygiene Laboratory for the past eight years for the determination of mercury vapour and dust from mercury compounds in the atmosphere over a range of 0·03 to 10·0 mg. mercury per cubic metre of air. The method employs the standard impinger for the collection of samples, followed by a simple colorimetric analysis by a slight modification of Polejaeff's method. A solution of 0·25% iodine in 3·0% potassium iodide is used in the impinger. The amount of mercury collected is determined by adding to an aliquot portion of the sample, usually 5 ml., 1 ml. of 1% copper sulphate solution, and 2ml. of ·3 N sodium thiosulphate solution. The pink colour of the suspension is compared with that of a standard. The overall efficiency of the impinger and analytical method was found to be about 90%. *H. M. Buckell.*

The Effect of Arsenical Vesicants on the Respiration of Skin. Thompson, R. H. S. (1946). *Biochem. J.*, **40**, 525.

In slices of normal rat skin sodium arsenite and lewisite inhibit to a considerable degree the small and additional oxygen uptake brought about by adding pyruvate, but produce relatively little effect on the additional oxygen uptake caused by succinate. Similar effects are observed when the oxygen uptake by normal skin is compared with that of skin previously treated *in situ* with lewisite. Hence it is concluded that the inhibitory effect in this case is a specific one on the pyruvic acid oxidation mechanism of the skin, and that it is not due to dilution of enzyme systems by œdema fluid. *T. R. Parsons.*

Chronic Thallium Poisoning. (Chronická otrava táliom.) Travnik, K. (1946). *Slov. Lek.*, **8**, 445.

Three Cases of Tetra-ethyl Lead Poisoning. (Tre tilfelle av forgifting med spalting spaltingsprodukter av blytetraetyl.) Bruusgaard, A. (1946). *Nord. Med.*, **32**, 2,644.

INDUSTRIAL LUNG DISEASE

The Utilization of Aluminium—In the Prevention and Treatment of Silicosis. HANNON, J. W. G. (1946). *Industr. Med.*, **15**, 527.

After a review of the development of aluminium as a therapeutic agent and the mode of action of silica, it is noted that the prevention of silicosis depends on : (*a*) dust control, (*b*) medical examination of the workmen, and (*c*) aluminium therapy to take care of the silica dust that cannot be " removed by a practical economic dust control programme." Aluminium inhalation in the treatment of 46 ceramic workers suffering from silicosis resulted in subjective improvement in 78% ; of these, 80% had 20% improvement in pulmonary function. [The statistical data are too vague to be significant.]

T. A. Lloyd Davies.

The Effect of Asbestos, and of Asbestos and Aluminium, on the Lungs of Rabbits. KING, E. J., CLEGG, J. W., and RAE, V. M. (1946). *Thorax*, **1**, 188.

The purpose of the authors' experiments was to test two questions : (*a*) whether short-fibre asbestos is less damaging to the lungs of rabbits than is the long fibre ; and (*b*) whether metallic aluminium will suppress any toxic effect produced by either the short- or long-fibre asbestos. The work of Gardner, who suggested a mechanical theory for asbestosis, is discussed. He concluded that asbestos exerts a pathogenic action only in tissues where rhythmic movements take place, and then only if the particles are of sufficient size to produce mechanical irritation. This is in contrast to the effects of quartz and of other forms of free silica.

The lengths of asbestos fibres were 2·5 μ and 15 μ, and 100 mg. suspended in 4 ml. of saline was used for each insufflation, which was performed monthly. Metallic aluminium was mixed with the asbestos in the proportion of 2 mg. to each 100 mg. of asbestos. Survival time of the animals was 3 to 19 months. Group I consisted of 12 rabbits treated with long-fibre asbestos (15 μ). The longer the survival time, the greater was the tissue reaction. It was of two types : first, the foreign-body reaction in which macrophages and foreign-body giant cells were associated with asbestos fibres ; secondly, overlapping the foreign-body giant-cell processes, there was a more permanent reaction resulting in the fixation of the asbestos *in situ*. This reaction was nodular in distribution and consisted of somewhat acellular areas of connective tissue, showing an increase of reticulin. These nodules were strictly comparable to, but less intense than, those produced by quartz. Group II contained 12 rabbits treated with long-fibre asbestos with aluminium. The two groups were strictly comparable, and it seems that the addition of aluminium increases and prolongs the foreign-body giant-cell reaction without inducing any marked inhibition of the second, more permanent reticulinosis. Group III included 7 rabbits treated with short-fibre asbestos (2·5 μ). Lesions here were more scattered, and affected the interstitial tissue and alveolar walls more widely. It is suggested as a reason for this that the process of phagocytosis is easier. There was considerable hyperplasia of the bronchial nodes, a feature not seen in the former experiments. There were still, however, some nodular areas of foreign-body giant-cell reaction. Group IV consisted of 9 rabbits treated with short-fibre asbestos and aluminium. The lesions were the same as those seen in group III but more severe.

The authors state that when asbestos is retained in the lung it excites a connective-tissue response ultimately leading to fibrosis. The site of the lesion depends upon the size of the asbestos fibre ; the long fibre, being too large for phagocytosis, is not expectorated and the reaction is intra-alveolar, whereas in the case of the short fibre the fibrous tissue is laid down in the alveolar walls and lymphatics. Possibly if fibres shorter than 2·5 μ were used they would be completely removed from the alveolar walls and fail to produce an interstitial fibrosis. The addition of the metallic aluminium appears to be without benefit and serves merely to enhance and prolong the foreign-body reaction.

Richard D. Tonkin.

Pneumoconiosis in Dockers dealing with Grain and Seeds. DUNNER, L., HERMON, R., and BAGNALL, D. J T (1946). *Brit. J. Radiol.*, **19**, 506.

This paper sets out to establish that pneumoconiosis occurs in dock workers who handle grain, and that the cause of this lies in the dust which they inhale from the grain itself. At a municipal dispensary 55 men were examined as possible cases of pulmonary tuberculosis. Of these, 30 were discarded as suffering from pulmonary tuberculosis ; the paper deals with the other 25. The men said they dealt mainly with grain (oats, barley, wheat, and maize), and with seeds (millet, cotton, dari, rape, and palm-kernel). These are shovelled from the ship's hold, an operation causing much dust, which the workers inhale ; the concentration is the greater owing to the confined space in which the work is done. The workers also handle bauxite, iron ore, sulphur, and manganese. The lighter fractions of the dusts were examined chemically, and expressed as percentages as follows :

Dust	Total silica in the sample	Soluble silica in the sample	Soluble silica in total silica	Ash
Wheat ..	5·4	1·28	23·8	11·4
Wheat ..	3·6	1·33	36·9	7·4
Oats ..	9·1	2·80	30·7	15·2
Maize ..	1·1	0·92	83·6	6·4
Barley ..	8·1	1·60	19·7	14·1
Barley ..	5·5	1·05	19·0	12·2

" Silica " included free or combined silica. Soluble silica was estimated by a modification of Matthews' method. Matthews found that the soluble silica in calcined flint dust known to be dangerous varied from 0·45 to 1·21% according to the fineness of the particles. This suggests that the grain dust is potentially dangerous. A sample of oat dust was found by *x*-ray diffraction analysis to contain 5% of free silica. Microscopically, the dust from wheat, oats, and barley contains starch, hairs, and cellular matter, and a large proportion of unidentifiable particles about 5 μ in size. Maize has few hairs. The silica particles were of the order of 1 to 3 μ.

Of the 25 men, 11 showed lesions attributable to inhaled dust ; in 14 the films were normal. The pneumoconiosis cases were grouped as follows :

Age when first seen ..	45	51	42	57	53	52	59	56	47	46	36
Duration of occupation	20	35	23	20	27	20	40	33	30	2	13

The symptoms were cough, sputum occasionally streaked with blood, and increasing dyspnœa, but some of the men with apparently normal radiographs had similar symptoms. The general condition was good. The radiographic changes were inconstant and asymmetrical

but are considered fairly typical of pneumoconiosis. Sputa were negative for tubercle bacilli after repeated tests; no other micro-organisms or moulds were found.

The authors consider that they have proved the connexion between the grain dust and the lesions shown radiographically, especially in view of the lack of history of pneumonia and similar conditions. They note that there is no fixed relation between the duration of occupation and radiological manifestation. They discuss the possible effects of the silica, the hair structures from the husk, and the chemicals which the men also dealt with. The radiologically normal cases were, on the whole, in rather younger men who had had fewer years of experience, but there were many exceptions. Four men complained of the same severe symptoms, but the *x*-ray picture was normal. No previous account of pneumoconiotic changes in grain workers has been described, but on the analogy of the occurrence of such changes in workers exposed to vegetable dusts in other occupations it seems highly probable they are to be seen also in men handling grain. *F. H. Young.*

Thresher's Lung. A Fungoid Disease Resembling Tuberculosis or Morbus Schaumann. [In English.] TÖRNELL, E. (1946). *Acta med. scand.*, **125**, 191.

Thresher's lung is a pulmonary disorder associated with inhalation of a large quantity of fungus-laden dust arising from mouldy grain during threshing. The symptoms, which are of rapid onset, are cough, sometimes accompanied by muco-purulent or even blood-streaked sputum, very marked dyspnœa on exertion, occasional vomiting, rigors, and fever. In the subacute and later stages, physical weakness and fatigue leading to incapacitation for work are prominent symptoms. The radiological picture of the chest shows a diffuse fine mottling of the lung shadow, most marked towards the hilum and lobar bases and less so towards the apices, strongly suggestive of tuberculosis. Removal from exposure to the dust brings prompt relief of symptoms in the early stages of the disease, and the improvement is accelerated by administration of potassium iodide.

The author gives detailed clinical descriptions of 9 cases of thresher's lung, and from these it appears that the disease is analogous to the condition known in England as farmer's lung, which is caused by inhaling the dust of mouldy hay. Seven of the 9 cases were tuberculin-negative, and the remaining 2 only weakly positive, which suggests to the author an analogy to lymphogranuloma benigna, in which a state of positive anergy to tuberculin occurs, and he considers that the diseases may be related to mycoses. In this connexion, also, he points to the tuberculosis-like character of thresher's disease, and refers to the work of Reenstierna and of Gullberg and Hollström on a supposed relationship of the tubercle bacillus to fungi of the genus *Candida* (*Monilia*).

The isolation of saprophytic fungi from the sputum of a person recently exposed to inhalation of fungus-laden dust can be accepted only as evidence of dust contamination of the sputum; but, while accepting this view, the author excepts yeast fungi of the genus *Candida*, which he found in the sputum of 7 of his cases. Although species of *Candida* are frequently present in the mouths of healthy persons, their pathological significance in the present cases is accepted and the hypothesis is advanced that thresher's lung may be caused by the simultaneous inhalation of *Candida* and particles of carbohydrate dust on which the fungus can vegetate. In conclusion, the author states that "everything goes to prove that the 'thresher's lung' is a bronchomoniliasis," but this surprising declaration is followed by the admission: "*Monilia* often appears as an insignificant saprophyte. Therefore the ætiology of the disease may only be secured after further experimental and clinical investigations." *J. T. Duncan.*

Thresher's Disease. (Die Dreschkrankheit.) HOFFMANN, W. (1946). *Schweiz. med. Wschr.*, **76**, 988.

During the 1945 harvest in the Appenzell region of Switzerland a strange disorder was observed in those operating threshing machines in poorly ventilated threshing-floors. The symptoms included prostration which forced the patient to take to his bed, unsteadiness on the legs, headache, cough, tightness in the chest, thirst, and anorexia; fever, appearing after a few hours, lasted 1 to 5 days and was followed by a slow recovery without sequelæ. Two groups of patients were seen: those engaged in threshing barley and those working with oats. Both crops had stood about in wet weather for some time and were dried for half a day before threshing; the grain in each case was discoloured grey. Mycological investigations showed 29% of the grains examined to be infected with a fungus, identified as *Chaetomium* (Ascomycetes). This fungus had previously been shown to be the cause of the "Taumelkrankheit" (Gerlier's disease). The different clinical picture in this outbreak is attributed to inhalation of the fungus.
R. Bodley Scott.

The Pneumoconioses, SANDER, O. A. (1946). *Industr. Med.*, **15**, 528.

The term "pneumoconiosis" originally meant a dust disease of the lungs, but it has become synonymous with fibrosis. Some dusts may be entirely inert in their effect on the lungs. Byssinosis (due to cotton fibre) and probably bagassosis (due to sugar-cane fibre) have an allergic basis, but in the latter the silica content of the sugar-cane fibre may cause cellular reaction. Tobaccosis (tobacco dust disease) has been disproved as an entity. *Monilia* and *Aspergillus* infections may simulate silicosis or silico-tuberculosis, and as these organisms may normally be present in the sputum and nasopharynx they cause difficulty in diagnosis. Coccidioidomycosis may rarely resemble silico-tuberculosis. "Wheatena," a miliary calcification of the lungs commonly seen in the grain areas of the Middle West of America, may be due to a fungus similar to aspergillus. Other fungus infections, such as blastomycosis, actinomycosis, sporo trichosis, and coniosporiosis, may rarely imitate silicosis.

Inorganic dusts, such as those of carbon, iron, calcium, carborundum, barium, tin, and possibly aluminium, apart from minimal foreign-body reaction, do not exert a fibrosing effect. The presence of *x*-ray shadows resulting from the inhalation of tin has not been verified. Artificial abrasives (carborundum and aluminium oxide) do not result in changes in the lungs which can be demonstrated radiographically. *X*-ray changes in the lungs of metal grinders are due not to silica but to iron, unless the metal articles which the men handle have been inadequately cleansed of silica. Siderosis, silicosis, and sidero-silicosis can often be distinguished radiographically. Silicatosis (due to talc), sarcoidosis, pulmonary vascular engorgement (due to mitral stenosis and polycythæmia vera), and, occasionally, metastatic carcinoma and miliary tuberculosis may sometimes simulate silicosis.

Diagnosis of pneumoconiosis is not enough; the cause must be identified. Abnormal radiographs and a diagnosis of pneumoconiosis do not always carry an unfavourable prognosis; even in nodular silicosis, providing it has developed slowly and is unaccompanied by tubercle, the outlook is not immediately gloomy and does not necessitate stopping work. The diagnosis of silicosis is unjustified unless all three fundamental criteria have been fulfilled: (*a*) nodular *x*-ray appearances; (*b*) history of adequate exposure to free silica dust; and (*c*) evidence of changes on physical examination and of impaired pulmonary function. The most frequently neglected factor is the industrial history, but to evaluate the effect of past work and dust exposure the physician must consult the industrial hygienist.

T. A. Lloyd Davies.

Pneumoconiosis in South Wales Anthracite Miners. GOODING, C. G. (1946). *Lancet*, **2**, 891.

This review of coal-miners' silicosis is based on clinical experience and pathological findings. The average survival period of 53 men certified as having silicosis with tuberculosis was only 22 months. In the author's series of 227 necropsies on certified silicotics it was found that 59 (26%) had associated tuberculosis and 41 (18%) had non-tuberculous respiratory affections; 84 (37%) had died from cardiac failure and 43 (19%) from unrelated conditions. Non-tuberculous infection usually takes the form of bronchopneumonia. Cardiac embarrassment is a common sequel or concomitant, especially in men with massive lesions. Only one case of primary lung cancer could be found in records of 400 necropsies. Preventive measures include water spraying, wet drilling, and the provision of an ample ventilating current to dilute and remove such fine dust as escapes the water traps. Hard headings are now considered safer than the coal face, where it is much more difficult to suppress dust, which is fortunately less harmful here.

Although the amendment of legislation of 1943 does much to prevent the march of silicosis, no person or authority has the power at present to keep the tuberculous man out of the pit, and until this stage of affairs is altered routine medical and radiological examinations can do little to prevent spread of the infection. *T. Semple.*

Employment of Ex-Tuberculous Patients. WILLIS, H. S. (1946). *Amer. Rev. Tuberc.*, **54**, 9.

The author pleads for the employment of ex-tuberculous patients in sanatoria and hospitals. He quotes the experience of the Maybury Sanatorium, Detroit, where occasionally ex-tuberculous patients have been employed. The sanatorium has 845 beds and normally employs 561 persons, 88 of whom have had tuberculosis previously. These 88 people worked altogether 559 man-years and collectively lost 10 man-years from tuberculosis.

To dispel the belief that this group of ex-patients was more than usually liable to absenteeism from conditions other than tuberculosis the author consulted the records of 58 of them, covering 152 man-years, or an average of 2·6 man-years each, and found a total loss of 1,527 days' work, or 10 days per person per year. This was compared with the record of 100 able-bodied employees, who were found to have lost 2,300 days from non-tuberculous ill-health, or 9·4 days per person per year. The records also showed that 26 employees who had no sign of tuberculosis on entry developed the disease while at work and between them had spent 30 years in hospital in consequence. "Thus three times as much absenteeism was experienced by 26 people who contracted tuberculosis while at work as was lost by the 88 employed ex-patients." This conclusion was deduced without any relation to the total number of employees involved or the number of years worked. The author admits the weakness of this when he adds that "those ratios are . . . only suggestive, because the numbers of able-bodied employees who did not develop tuberculosis are unknown but large." The group of 88 ex-patients proved more stable than the average, with less turnover.

[It would be unwise to assume from the author's figures that the time lost by fresh cases occurring in the able-bodied would be three times that lost by relapses in a staff wholly composed of ex-patients. The ratio might be the other way round, and experience with mass radiographic surveys suggests that it would be. But the problem is not a mathematical or even entirely an economic one; it is largely one of therapeutic rehabilitation. The environment and amenities of the sanatorium are frequently ideal for the person with arrested or quiescent tuberculosis, and the author is probably right when he says that better work is often obtained from these than from the healthy. In Great Britain those who have tried the experiment have so far no reason to be displeased.] *N. Lloyd Rusby.*

INDUSTRIAL PHYSIOLOGY

Heat Rash as a Problem in the Naval Service. DUFFNER, G. J. (1946). *Amer. J. trop. Med.*, **26**, 539.

Heat rash, known also as prickly heat or miliaria rubra, is due to excessive heat. The dry-bulb temperature below decks is always 7° to 10° F. above that of the weather temperature. During naval operations in the Pacific, ships were forced to spend long periods when no ventilation equipment was in operation, and at sunset ships were darkened and all weather accesses closed. On a modern well-ventilated battleship 70% of the crew were sleeping in spaces in which the temperatures were high enough to produce heat rash. The pricking, burning, and itching of the skin which accompany this condition cause insomnia, and man-hours are lost when men report several times daily to the sick-bay to have lotions applied to their skins. Approximately 40% of personnel reporting sick complained of heat rash.

Experiments were designed at the Naval Medical Research Institute to study heat rash. In the first of these, 10 volunteers (the "hot group") were selected at random to live under conditions simulating those aboard ship in the tropics. The group worked 7 hours a day in a room maintained at 108° F. dry bulb and 83° F. wet bulb—an effective temperature of 90° F.—and spent the remaining 17 hours of the day in another room maintained at 95° F. dry bulb and 83° F. wet bulb—an effective temperature of 87° F. The work for each man consisted in walking on a treadmill. A similar group of 10 volunteers (the "cool group") was selected for the second part of the experiment. They worked 7 hours a day in the hot treadmill room, but the remaining 17 hours were spent in an environment of 85° F. dry bulb and 71° F. wet bulb—an effective temperature of 78° F. Each group continued its programme for 10 days without interruption. All the subjects in the "hot group," but only 1 in the "cool group," developed heat rash. A further similar experiment lasting 30 days was undertaken. All except one

subject in the "hot group," and none in the "cold group," developed heat rash.

The conclusion to be drawn from these experiments is that spending as little as 12 hours a day in an atmosphere in which one does not sweat at rest (78° F. effective) will give rise to heat rash. The investigators found no correlation between the *p*H of the sweat, sweating rates, and the incidence of severity of heat rash. Formalin electrophoresis, taking or abstaining from shower baths, and pressure bandages over certain areas, did not affect the course of the disease. Exposure to ultra-violet light ameliorated the condition in some cases and aggravated it in others. The pathological changes found by biopsy in one case of experimentally produced heat rash were: (1) the epidermis is hyperplastic; (2) a blister forms in the stratum lucidum and is unrelated to the sweat gland or hair follicles; (3) the dermis is œdematous; (4) some of the inflammatory cells infiltrate the epidermis. Heat rash represents a serious problem aboard ship in the tropics and can be prevented by short periods of cooling.

Geoffrey McComas.

Decline in the Rates of Sweating of Men working in Severe Heat. GERKING, S. D., and ROBINSON, S. (1946). *Amer. J. Physiol.*, **147**, 370.

An experiment was carried out on men well acclimatized to heat who were walking on a treadmill at a high temperature for periods of 6 hours. The men retained their water balance by drinking saline. The average rate of sweating in the first 2 hours was 1,400 g. per hour; the rate declined thereafter by from 10 to 80% by the sixth hour. The decline depended on environment. It was greater in humid atmospheres, when the initial rate was high, and when the men wore clothes.

Raymond Greene.

Exchanges of Heat and Tolerances to Cold in Men exposed to Outdoor Weather. ADOLPH, E. F., and MOLNAR, G. W. (1946). *Amer. J. Physiol.*, **146**, 507.

Men nearly nude were exposed on the roof of the laboratory to different temperatures ranging from uncomfortably hot to bitterly cold. Their reactions were tested over periods of 1 to 4 hours by measurement of their pulse rates, arterial pressures, rectal and surface temperatures, urinary flow, oxygen consumption, respiration rate, blood concentration, and blood sugar content. Over a wide range, skin surface temperatures were proportional to air temperature, whereas rectal temperatures were nearly constant, falling only to 96° F. (35·6° C.) after 4 hours' exposure to air at 46° F. (7·7° C.). The temperature of the extremities was close to that of the dry-bulb temperatures of the air. As might be expected, wind had an obvious cooling effect on surface temperatures.

In order to maintain internal heat various mechanisms are employed. Of those tested in this series of experiments the most important was shivering, during which oxygen consumption increased as much as fivefold. Vasoconstriction naturally occurred and was accompanied by the other well-known sympathetic phenomena. Hæmoconcentration took place, the blood volume being diminished by extreme cold by as much as 850 c.cm. The blood sugar was not significantly changed during chilling, but rose rapidly during subsequent warming. In extreme cold the subjects became stuporous and mentally confused. After rewarming they were sleepy and fatigued and usually lost their appetites for some hours. Acclimatization was not observed.

[It must be pointed out that the experiments continued for only 3 months and were, moreover, intermittent.] *Raymond Greene.*

Vibration Syndrome in Industry. DART, E. E. (1946). *Industr. Med.*, **15**, 481.

A report on "the evaluation of vibration syndrome in industry," presented to the Industrial Health Conference at Chicago in April, 1946, referred to 114 persons who were exposed to vibrations of 12,000 per minute. There was pain in 68%; numbness in 41%; stiffness in 28%; paræsthesia in 9%; dropping of objects by 8%; sensation of cold in 7%; cramps in 7%; and weakness in 7%. The objective signs were mainly swelling, erythema, and cyanosis, but 55 of the group showed no objective signs. A method of taking the temperature of both hands was described, including immersion of the hands in water at 35° F. (1·6° C.) for 5 seconds and periodic temperature-taking afterward. Lantern slides were shown of normal and abnormal tone (basomotor tone) and also of hands which did not return to normal after 15 minutes.

All but 43 of the 114 persons showed pathological changes. The age distribution was comparable in the controlled groups; in the groups studied, 78% were females. Apparently there was no correlation with the type of job. There was much seasonable variation, the difficulties occurring in the colder weather. The right hand was the one which showed the symptoms most, though there was a delay in the cold response in both at times. The position of the tool seemed to have some significance. Two conclusions were reached: (1) peripheral vascular disturbances may be present without demonstrative changes; and (2) the vital tissues react differently at different speed ranges (for example, there are differences in the 4,000 vibrations per minute as contrasted with the 10,000 vibrations per minute). *From the Official Report.*

ACCIDENTS AND ORTHOPAEDIC SURGERY

Flash Burn Preventive Cream. GLICKMAN, C. S. (1946). *Austral. pharm. Notes*, **25**, 115.

A cream was needed to guard against flash exposures of high temperature. It had to be quick-drying, non-toxic, removable with soap and water, unaffected by sweat or salt water, and yet permitting normal skin excretion. A major problem was to determine the efficacy of experimental products. Thirty-seven basic experiments with very many possible constituents resulted in the following formula:

	%
Bleached dewaxed shellac	13·70
99% isopropyl alcohol	28·48
Bodied linseed oil—Z-3 viscosity	3·50
Triple pressed stearic acid	0·15
Triethylene glycol di-2-ethylhexoate	0·80
Diethylene glycol monoethyl ether	1·10
Titanium dioxide—cosmetic grade	37·00
Sodium bicarbonate	2·25
Magnesium stearate	8·00
Methyl salicylate	2·50
Sulfonated alcohol wetting agent	0·30
Iron oxide (lemon shade)	1·60
Mineral black	0·62
(All percentages by weight)	100·00

Tests were made by igniting charges of 5 g. of potassium chlorate, sugar, and magnesium powder in a "gun" made of a metal tube with a sparking plug. Later a

smokeless powder or cordite charge ignited by a fuse was used instead. The flashes were directed at 20 cm. range against filter paper coated with the protective creams. An unprotected paper was charred or perforated, whereas an adequately protected paper was only slightly browned. Live rabbits were sufficiently protected by this cream, and later men who had been swimming in salt water were exposed experimentally to flashes and suffered only very mild burns. The cream must form a non-rigid, finely reticular film in order not to limit the movements of the wearer or to flake off; this one passed successfully a test of 30 hours' wearing to determine its lasting properties. Discomfort was minimal. Details of large-scale manufacture and the costs are given. The product was filled by positive displacement into flat 4 oz. (113 g.) tins, and later into collapsible tubes. The cost was 23 cents per tin.

[There may be many post-war uses for such a cream in industries when there is a risk from heat or an open flame.] *J. N. Agate.*

Picric Acid in the Treatment of Chemical Lesions of the Eye with special reference to those caused by Caustic Soda. (L'acido picrico nella cura delle lesioni chimiche dell'occhio con speciale riguardo a quelle da soda caustica.) BELLESINI, C. (1946). *Med. Lavoro*, **37**, 222.

The immediate reaction of the eye to caustic soda, lime, strong alkalies, and strong acids is a ground-glass appearance of the cornea with considerable pain. The pupil is contracted and does not react to atropine. Fragments of solid caustic cause corneal injuries, while solutions cause conjunctival injuries, particularly in the lower fornix. In mild cases the conjunctiva is turgid and red, but in severe injuries it is pale and whitish, with petechial hæmorrhages. After 6 hours or more, pain becomes severe. The epithelium desquamates, leaving the cornea bare. Large, deep ulcers appear, without inflammatory reaction. Healing is slow. A superficial lesion is followed by an ill-defined opacity, without the surrounding blood vessels usually seen around opacities from other causes. Minor conjunctival injuries leave the conjunctiva œdematous and congested, secreting mucus and slow to recover. In severe cases a slough forms which is slow to separate, leaving indolent granulations. Symblepharon is inevitable unless the lesion is confined to the palpebral fissure.

The author has treated altogether 200 cases which have been caused mostly by caustic soda, although some have been due to sulphuric and nitric acids combined, sulphuric acid alone, hydrochloric acid, lime (quick and slaked), liquid ammonia, acetic acid, and potassium bichromate. The principles of treatment are: (1) elimination of as much caustic as possible by copious irrigation, paying particular attention to the fornices; (2) neutralization of the caustic already attached to, or embedded in, the tissues; (3) treatment of the ulcerative condition and encouragement of healing. The first principle is easily put into practice with plenty of dilute acid or alkali in isotonic solution. For (2) and (3) the author found picric acid very good. It was applied, in a 2% ointment with a petroleum jelly base, twice daily. The eye was cocainized first. There was an immediate disappearance of pain (ascribed to the picric acid, but probably due to the cocaine), and after 24 hours the corneal opacities, even when they were deep, cleared. Desquamation was prevented, and where it had already occurred healing was rapid. Conjunctival reactions were minimal, with little œdema and mucus secretion. Pupillary reactions were quick to return to normal, and healing was complete after 6 or more days, according to the severity of the injury. [No follow-up is given, and no controls are quoted —e.g., with neutralizing lavage alone.]

Tom Rowntree.

The Medical Rehabilitation of the Disabled. BOER, H. A. de (1946). *Int. Labour Rev.*, **54**, 29.

Injuries due to Strain and their Relation to Accidents. (Uberlastungsschäden und Unfallbegriff.) BAUMANN, E. (1946). *Z. Unfallmed. Berufskrankh.*, **39**, 342.

Plastic Surgery and Social Insurance. (A plasztikai (rekonstrukciós) sekészet szerepe a társadalombiztositasban.) ERCZY, M. (1946). *Orv. Lapj-a.*, **2**, 984.

The Constitution in Industrial Medicine and Accidents. (De l'état constitutionnel en médecine du travail et des accidents.) OLTRAMARE, J. H. (1946). *Z. Unfallmed. Berufskrankh.*, **39**, 315.

Technical Preventive Measures and the General Causes of Accidents in Industry. (La prevenzione tecnica e le cause generali dell'infortunio.) MAURELLI, C. (1946). *Securitas, Milano*, **31**, 2.

GENERAL

Industrial Hygiene in Relation to Dock Labourers. (Higiene laboral del obrero de carga y descarga.) DE MEMBRILLERA, D. F. G. (1946). *Bol. Segur. Hig. Trab.*, **7**, 4.

The author stresses the importance of careful selection of men engaged in heavy work such as loading and unloading. The hernial orifices and the arches of the feet need attention, while radiography of the spine to exclude abnormalities or old injuries is advisable. Old injuries are important for future evidence in compensation cases. When the workman is engaged he should receive instruction in the use of protective equipment. The work done by these men, and the lesions discovered, are varied. About 10% have a lipomatous swelling on the shoulders, attributed to repeated pressure of the loads carried. Spondylitis is common, especially in the dorsal region; it is probably of traumatic origin and is often first discovered when a radiograph is taken because of lumbago. Associated radiculitis is common. Over 50% of the accidents in these men are described as lumbago, and the author thinks that in many there is actual tearing of muscle fibres. A radiograph should be taken in any case of lumbago lasting more than 10 days, because often some bony abnormality is found.

Many of the substances handled by these heavy workers are in powder form, e.g. cement, which is irritating to the nasal mucosa, especially if there is deformity of the septum or turbinates. Ulceration may occur in the nose. Some authorities believe that the addition of powdered aluminium to cement lessens its irritant properties. In Spain the advice to use masks meets with some resistance. Calcium cyanamide, used in agriculture, is difficult to handle. On contact with water it liberates calcium hydroxide which burns the skin and mucous membranes. Complete protective clothing is necessary but is uncomfortable to use. It has been observed that men who take alcohol within

24 hours of undertaking this work suffer localized œdematous areas on the face and neck with some reddish-blue coloration.

In about 90% of a moderate number of necropsy examinations on dock workers, hepatic changes of the cirrhotic type, and pneumoconiotic lesions, were found. The author considers that liver changes are alcoholic in origin in about 60% of cases and that 10% of industrial accidents are due to alcoholism. Self-inflicted injuries are not uncommon, and are usually due to a heavy object being dropped on the hand or foot. This is unlikely to happen when the workman is sober. In the author's view about 70% of Spanish dock workers are infected with syphilis. About 4% of men between the ages of 30 and 45 are unemployable because of syphilitic infection. The insurance company which handles accident cases insists on a blood test if a wound is slow in healing: of those tested, 60% give positive results. Dock workers should be adequately fed, and to this end and with a view to diminishing alcoholism the port authorities in Spain favour the provision of canteens where good food is sold at reasonable prices. The use of shower baths at the end of the day's work is encouraged, and in some places is compulsory. This helps to diminish the incidence of dermatitis. *G. C. Pether.*

Inability to Work in a Tropical Climate. TRENCHARD, H. J. (1946). *Brit. med. J.*, **2**, 416.

This paper discusses 373 R.A.F. personnel from 18 to 47 years of age but mainly between 20 and 30, chiefly ground staff, who, between October, 1944, and September, 1945, were found unfit for duty in South-East Asia, although not necessarily unfit for further military service in the United Kingdom. Most had been in the R.A.F. between 2 and 5 years, service overseas varying from 2 to 51 months; the incidence of invaliding, excluding that due to tropical diseases, showed peaks during the first 12 months, and after 18 months of service overseas. The principal causes of invaliding were: injuries, 50; organic diseases—excluding pulmonary tuberculosis, which was not dealt with at this centre—176; psychological abnormalities, 147. The majority of the invalided were fit to travel by normal trooping arrangements, only 60, of whom 18 had injuries, requiring transport by hospital ship.

Only 5 injuries were directly due to enemy action. Disorders of the urinary system, particularly calculus, were frequent. Fifty patients had skin diseases (epidermophytosis 12 and seborrhœic dermatitis 12), of whom 10 had trouble before going overseas. Tropical diseases accounted for 59 invalidings (spine, 34; amœbiasis—amœbic hepatitis, persistent relapses of bowel infection, and the development of a "pre-sprue type of condition"—15); only 2 patients were invalided with malaria, a low figure thought to be due to the efficiency of mepacrine. Anxiety state was diagnosed in 86 patients, hysteria in 33, psychoses, mostly schizophrenia, in 15, and psychopathic personality in 11. The principal precipitating factors of the anxiety neuroses appeared to be family or financial worries, infidelity of the wife, or discomforts of overseas service, but in 15 cases no outstanding factor could be discovered. In those suffering from hysteria, the precipitating cause appeared to be a subconscious desire to return home, while the principal symptoms were headache, depression, dizziness, or dyspepsia. A feature of the psychotic patients and those diagnosed as being of psychopathic personality was the length of time that they were able to serve overseas before requiring invaliding; some carried on for more than 2 years. *F. Mugatroyd.*

Better Use of Laboratory Procedures—For More Accurate Diagnosis in Industrial Medicine. DREESSEN, W. C., and SIEVERS, R. F. (1946). *Industr. Med.*, **15**, 621.

Laboratory tests are important in diagnosis, but their value should not be over emphasized. The physician must know the limitations and facilities of the laboratories in his area, and must realize that the procedures involved in his requests often require such elaborate equipment and technical knowledge that the ordinary clinical laboratory cannot provide reliable results. Three types of test are discussed: (1) specific tests which determine quantitatively the amount of a toxic agent present in biological fluids or materials; (2) tests which measure a metabolic or conjugated product of the toxic agent; and (3) tests which measure physiological disturbances or detect structural changes in organs and tissues. These are presented in three comprehensive tables which show at a glance the normal levels of toxic agents or their metabolic products in the biological materials used for analysis, and the upper limit of safe absorption or figures indicating abnormal absorption. The author condemns routine demands for tests on a "hit-or-miss" basis in the hope of an early diagnosis and appeals to industrial physicians to make proper use of laboratory procedures. *A. Lloyd Potter.*

The Role of the Laboratory in an Industrial Hygiene Program. KOVEN, A. L. (1946). *Industr. Med.*, **15**, 628.

Examples of the part played by the industrial hygiene laboratory in solving the problems of differential diagnosis of occupational diseases are given. Among the functions of the laboratory are the following: to differentiate between occupational and non-occupational diseases; to rule out erroneous occupational causes and determine the proper hazard; to give a qualitative and quantitative basis for engineering surveys and recommendations for control; to recommend the substitution of less toxic materials; and, as a result of routine analyses, to reveal unsuspected hazards.
A. Lloyd Potter.

An Apparatus for Dispersing Finely Divided Dusts. SONKIN, L. S., LIPTON, M. A., and VAN HOESEN, D. (1946). *J. Industr. Hyg.*, **28**, 273.

Occupational Therapy. (La therapeutique occupationnelle.) LAFON, J. L. (1946). *Med. Francais, Paris*, **6**, 374.

Principles of Acknowledging Compensation Claims for Arthritis. ENGLEHART, E. E. (1946). *Industr. Med.*, **15**, 626.

Hygienic and Sanitary Conditions in Drug Industries. (Étude sur les conditions de l'hygiène et de la salubrité dans les industries pharmaceutique.) RAYMOND, V., and DESOILLE-MERLHES, P. (1947). *Bull. méd.*, **3**, 25.

Syphilis and Industrial Injuries. (Syphilis et traumatismes du travail.) BARTHELEMY, R. (1947). *Bull. méd.*, **3**, 33.

The Development of Indemnity Legislation in Industrial Accidents and Occupational Diseases. (Evolution de la législation sur la réparation des accidents du travail et des maladies professionnelles.) DESOILLE, H. (1947). *Bull. méd.*, **3**, 37.

PROCEEDINGS OF THE ASSOCIATION OF INDUSTRIAL MEDICAL OFFICERS

FORTY-SIXTH MEETING

The forty-sixth meeting of the Association was held on Friday and Saturday, Jan. 24 and 25, 1947, at the London School of Hygiene and Tropical Medicine. Dr. W. Blood (London) was in the chair.

The Chairman welcomed Dr. L. S. Potter to the Meeting as the representative of the British Medical Association.

New Members

Ten Ordinary Members and three Associate Members were elected.

National Advisory Committee for Rest Breaks

Dr. J. A. Mekelburg (London) was appointed as the Association's Representative on this Committee vice Dr. Patricia Shaw (Nottingham) who resigned.

Joint Meeting of the Association and the School Group of the Association of Medical Officers of Health

A joint meeting of the School Medical Service Group of the Society of Medical Officers of Health and the Association of Industrial Medical Officers was held on Jan. 24, at the London School of Hygiene and Tropical Medicine. Dr. J. B. Morgan, President of the School Medical Service Group of the Society of Medical Officers of Health, and Dr. W. Blood, Chairman of the Association of Industrial Medical Officers, presided jointly; 120 persons were present. A discussion on "The Change from School to Industry" was opened by Dr. A. A. E. Newth, Senior School Medical Officer of Nottingham, and Dr. T. A. Lloyd Davies, Chief Medical Officer of Boots Pure Drug Co. Ltd., Nottingham.

Dr. A. A. E. Newth of the School Medical Service Group in opening the discussion observed that interest in the health of the school child was due largely to the realization that it did not pay to try to give education to the child who was not well enough to benefit by it, and that the foundations of ill-health in the adult were generally laid in childhood. He supposed that industrial medicine existed because industry could not get the best out of the employee who was ailing and that it paid to provide good conditions for the workers. These were important practical considerations, not sentimental ideals.

During his school life the health of the school child had been carefully guarded. Every effort was made to provide a curriculum suited to the needs of each child. The modern school was a healthy place and great care was taken of the physical health of the children. The School Health Service did its best to prevent and remedy defects and, with the Child Welfare Service as a valuable ally, was turning over to industry a much healthier person than it did a few years ago. But its control of child health was far from complete. Unpreventable illnesses left handicapping scars. Further, the child left school for industry when he was physically and emotionally immature. The work of the examining factory surgeon, perhaps carried out under not too favourable conditions, must be difficult. Could it not be helped by a closer consideration of the previous medical history, the records of which remained unasked for in the files of the school medical officer, who was anxious that this confidential information should be used for the benefit of the employee and not to enable the employer to reject recruits who might embarrass him later. Who was the best person to carry out the duties of the examining factory surgeon? The factory with its limitations of recreation could not surely be as healthy a place as the school. There were certain children who were permanently handicapped. What happened to them in industry? Did the highly organized firm with its efficient industrial medical service want the young person who was not so fit? If so, was there not a danger that he might be allowed to drift into employment where there might be less careful supervision? It might be that industrial medicine could suggest to the School Health Service how better to prepare the child for industry. By working in harmony the two services might be able to fulfil some of the highest ideals of preventive medicine.

Dr. T. A. Lloyd Davies, of the Association of Industrial Medical Officers, recalled that the Factories Act of 1833 required part-time education of juveniles under the age of 14 working in industry. Unfortunately, subsequent Acts did not continue this provision, and education and industry were not again associated until the Education (Fisher) Act of 1918. This Act permitted the establishment of day continuation schools but only one local authority (Rugby) and a few firms took advantage of this provision. Not until 1950, under the Education Act, 1944, would county colleges become compulsory throughout the country, and the link between school and industry firmly established.

The change from school to industry was abrupt and took place at a time when special physical and psychological stress occurred. At school, work was done in an interesting manner for short periods; free dinners and milk were provided, and medical supervision was continuous. In industry work was long, dull, and uninteresting, and its purpose was seldom explained to the child. Canteens were now regarded as an industrial asset; but except in a few specified jobs, such as night work, there might be no further medical supervision. Children entering industry showed few examples of gross disease, but many of remediable minor defects. Many of these were a reflection on the social circumstances. Greater use should be made by the examining surgeon of the reports to which he was entitled under the Factories Act from the School Health Service. The actual placement of the child in industry should be made by the industrial medical officer, who had an intimate knowledge of work and industrial conditions. Dr. Lloyd Davies' work as medical officer to the day continuation school, established since 1920 by Boots Pure Drug Co. Ltd. and the City of Nottingham, had brought

him in close contact with the School Health Service. The help that he had always received from Dr. Newth had convinced him that much was to be gained from co-operation between the medical services in schools and factories.

Adolescence was a time of change, of instability and of extreme susceptibilities. A sense of uniqueness of experience was felt by the adolescent; loneliness and doubt caused much unhappiness. The young person found factory work dull and boring. The zest was taken out of life. The industrial medical officer might find that after a few weeks a recruit had "settled down," but actually his spirits might have been broken and his instincts dulled. Girls were able to perform repetitive work better than boys. The latter must have satisfaction in their work, otherwise they became frustrated and bored or developed psychoneurotic illness or left. Delinquency did not increase after entry into industry, though the type of crime altered. Above all, the adolescent needed work. The tragedy of mass unemployment must never be repeated. County colleges provided a glorious opportunity to fill the gap in knowledge of the development of the normal adolescent. Experience of being associated with day continuation schools could not fail to give great faith in the future generation. The aim of county colleges should be to provide a liberal education so that the change from the discipline and responsibility of school to the freedom of the adult was not harmed by the self-seeking and trashy achievements of industrialized work. Dr. Lloyd Davies' work in a day continuation school had given him great faith in the future. Boys and girls now entering industry were magnificent. Given the opportunity, they would create a world in which the abilities of the citizen were matched with a sense of responsibility and duty to fellow citizens.

The papers were followed by a discussion in which speakers advocated the adjustment of the machines to the requirements of the workers on recognized scientific lines, and asked that the child on entry should be given opportunities of seeing varying aspects of the work before deciding on apprenticeship in any particular branch. Others considered that the young employees should meet employers, industrial medical officers, school medical officers, and representatives of the juvenile employment bureaux to discuss their problems. With regard to the examining factory surgeons, one member mentioned that there were certain difficulties in getting the industrial medical officer appointed as examining surgeon, a policy which he considered advisable. A good deal of the discussion turned on the employment of disabled persons under the provisions of the Disabled Persons (Employment) Act. It was noted that, although various types of disablement were mentioned, such as epilepsy, heart disease, and blindness, none pleaded for the deaf. The Chairman, in closing the discussion, spoke of the value that the meeting had been for both branches of medical service and expressed the hope that similar meetings should be held at future dates.

Discussion on Intervertebral Discs

At a meeting held at the London School of Hygiene on Saturday, Jan. 25, Mr. R. H. Young, F.R.C.S., gave an address on "Diagnosis, Pathology, and Treatment of Intervertebral Discs," illustrated by a colour film. "Almost all cases of recurrent sciatica," he said, "are disc lesions." A positive diagnosis could be made on the history and back signs alone, the latter being a limitation of forward bending, associated with unimpaired lateral bending. Backache was a common initial symptom, and recurrent backache with physical signs pointed to disc lesion. The pathology of the condition consisted in either a tear of the annulus fibrosis (which was commonest), or a protrusion of the nucleus pulposus, causing, in both cases, irritation of the nerve root. Any disc might be affected, but the commonest was between the fourth and fifth lumbar vertebræ. There was no satisfactory method of localizing the lesion. Treatment was conservating for the first attack, and operation for persistent symptoms, consisting of a laminectomy and removal of the protrusion. Exercises began twenty-four hours after operation, and the patient was considered fit for any work at the end of a year. Eighty per cent. of cases operated on between 1938 and 1945 had been free from symptoms.

Dr. N. L. Lloyd opened the discussion on behalf of the Association. Mr. T. Eldon Stowell gave some interesting information on the incidence of disc lesions in industry. In the survey of a light industry, he found that 3·8 per cent. of men and 2·8 per cent. of women were liable to this injury, as against a heavy industry (exemplified by an establishment for testing armoured vehicles) in which 7·6 per cent. men developed lesions.